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China Report

SCIENCE AND TECHNOLOGY

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20 February 1985

CHINA REPORT
SCIENCE AND TECHNOLOGY

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PEOPLE'S REPUBLIC OF CHINA

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ABSTRACTS

NATIONAL DEVELOPMENTS

LI ZIQI SPEAKS AT FORUM ON SCIENTIFIC RESEARCH

HK220325 Lanzhou Gansu Provincial Service in Mandarin 2300 GMT 20 Jan 85

[Text] On the afternoon of the day before yesterday [19 January] and yesterday morning [20 January], the provincial CPC committee invited some leaders, experts, and scholars of the central scientific research units in Lanzhou and universities and colleges to a forum in the (Yinwozhuang) guesthouse to discuss the problems of speeding up the popularization and application of the achievements in scientific research and of promoting the economic take-off in Gansu. Attending the forum were responsible comrades of the provincial CPC committee and the provincial government, including Li Ziqi, Chen Guangyi, Liu Bing, Jia Zhijie, Liu Shu, (Lu Ning), and (Li Shiwei).

At the forum, comrades of the scientific research units put forward many very good views and suggestions on how Gansu can further give play to the role of scientific research units and speed up the popularization and application of scientific and technological achievements. The responsible comrades of the provincial CPC committee and the provincial government attached great importance to the views and suggestions which were put forward. They expect to formulate relevant specific measures to solve these problems after the forum.

At the conclusion of the forum, Li Ziqi, secretary of the provincial CPC committee, spoke. He said that over the past few years, the central scientific research units in Lanzhou and universities and colleges have made active contributions toward invigorating Gansu's economy. Comrade Li Ziqi also pointed out that in the course of reform, scientific research departments must link scientific research with production and education and must expand exchanges of technology and information in scientific research work. Economic management departments in the province must strive to do well in serving scientific research and must formulate regulations and measures which are beneficial to scientific research work so as to further arouse the enthusiasm of scientific research work so as to further arouse the enthusiasm of scientific research personnel. Moreover, it is hoped that all scientific research units, universities, and colleges will make more achievements in scientific research and provide more qualified personnel for scientific research so as to make our province's economy take off at an early date and to make preparations in all aspects for exploiting the great northwest of China.

CSO: 4008/186

NATIONAL DEVELOPMENTS

STATE EQUIPS FIVE KEY RESEARCH LABORATORIES IN HIGHER INSTITUTIONS

Beijing ZHONGGUO JIAOYU BAO in Chinese 27 Oct 84 p 1

[Text] Among the ten key laboratories which have been designated for direct funding by the State, five will be located at institutions of higher learning. The first installment of the funding reportedly has been released by the National Planning Commission and the Ministry of Finance.

The five key laboratories to be constructed are: the "Solid-State Micro Structure Physics Laboratory" at Nanjing University, the "Crystal Material Laboratory" at Shandong University, the "Genetic Engineering Laboratory" at Fudan University, the "Enzyme Engineering Laboratory" at Jilin University, and the "Ultra-High-Speed Laser Spectroscopy Laboratory" at Zhongshan University.

The Ministry of Education has invited many Chinese authorities and experts to provide individual evaluations of the construction plans of these five laboratories. The experts unanimously agree that efforts by the State to invest in key laboratories at selected higher institutions are highly significant. They believe that faced with the challenge of technology revolution and production development, there is increasing need for high-standard laboratories and highly qualified technical personnel. They fully support the idea of "three fronts" and promote the establishment of "two centers", i.e., education center and research center, at the higher institutions. Providing financial support to higher institutions to develop a number of open experimental bases should be a long-term and persistent policy of the State.

The experts give highly favorable evaluations to the existing foundations of these five laboratories. They are impressed by the highly qualified technical leadership and the logically structured research team; they are also impressed by the clearly defined and important research goals, as well as the solid foundations and the unique potentials for conducting research. The standards of some of the research work rank among the top in the nation; they can even match the international standards. During the review of the Solid-State Micro-Structure Physics Laboratory, Prof. Chian Linzhao, academic committee member of the Chinese Academy of Sciences, pointed out that the highly capable Nanjing University research team headed by Prof. Du Fengduan and Prof. Wang Yehning had made significant contributions in the areas of crystal imperfections, structural phase changes, crystal growth, and internal dissipation. It is one of the major research centers of solid-state physics in China, and plays an

influential role internationally. Therefore, Nanjing University is a logical choice for the site of such a laboratory. Some scholars believe that with the existing solid foundation and the promised state support, this center will undoubtedly rank among the top teams in the world in 3-5 years. In evaluating the Crystal Material Laboratory of Shandong University, the experts agree that since 1958, Shandong University has developed many techniques of growing crystals, and has produced crystals for more than 40 applications including non-linear optics, laser, piezo-electricity, ferro-electricity, and thermal electricity; some of these crystals have attained international advanced standards. The University has provided valuable research results and practical crystal materials for various organizations supporting the national defense and the national economy. It has become one of the highly regarded crystal material research and development centers.

The experts predict that with the completion of these laboratories, significant achievements in various scientific fields can be expected. For example, Fudan University has a solid foundation and a powerful team in the field of genetics and genetic engineering; indeed, it has already made encouraging progress in genetic engineering research. It is expected that by 1988, the application of genetic rearrangement technique will reach sufficient maturity to make a positive contribution toward the establishment of an interferon production facility. The Crystal Material Laboratory at Shandong University will have the capability to develop various important single crystals and associated components and equipment in a number of high-technology areas, and to better explain the crystal growth mechanism and the strange physical phenomena exhibited by crystals in order to provide a foundation for developing new materials. The Solid State Micro Structure Physics Laboratory of Nanjing University will be able to carry the traditional research of crystal imperfections and structural phase changes to the atomic level, and to expand the scope of research to include mineral crystals, liquid crystals, and non-crystal materials; in addition, it will develop new materials with special micro structures (e.g., modulated structural materials), super-fine particle structural materials, and explore ways to use these materials in practice. In short, these key laboratories will play an important role in both theoretical research and in practical applications.

Evaluations given by the experts indicate that in many scientific disciplines, institutions of higher learning are already ranked among the foremost organizations in the country and are well equipped to provide training for highly qualified technical personnel. But over the years, their potential could not be developed due to lack of research funds and inadequate facilities. The experts believe that by investing wisely in certain key laboratories, one can expect to see immediate returns in terms of the ability to train high-level specialists and to raise the standards of certain scientific fields to the same level as those of advanced nations in the world.

3012
CSO: 4008/174

NATIONAL DEVELOPMENTS

HEALTH MINISTRY REFORMS RESEARCH MANAGEMENT

OW240043 Beijing Xinhua Domestic Service in Chinese 0736 GMT 22 Jan 85

[By reporter Zou Peiyan]

[Excerpts] Beijing, 22 Jan (XINHUA)--The reporter has learned from the National Conference of Heads of Public Health Departments that the Ministry of Public Health has decided to reform the management of medical and hygienic research plans throughout the country. Beginning this year, the ministry will experiment with the bidding system for various research projects, and the foundation system for scientific research funds.

The experimentation on the bidding and foundation systems will change the former way of appropriation of scientific funds. They will link scientific research tasks with funds, scientific investments with research results, and duties with powers and benefits. Thus, the former practice of "sharing food from the same big pot" will be overcome. The new systems will contribute to turning scientific research results into a productive force, mobilizing scientific personnel's initiative and creativity, and bringing into play the motive force and vitality of scientific research units.

Representatives of scientific research units and medical colleges at the meeting commented that this was an important reform measure in the management of medical and hygienic research.

CSO: 4008/186

NATIONAL DEVELOPMENTS

TWO IMPORTANT ISSUES IN REFORM OF S & T SYSTEM

Beijing RENMIN RIBAO in Chinese 11 Dec 84 p 3

[Article by He Zhongxiu [0149 6988 4423]]

[Text] The reform of S & T system includes reforms in organization structure, in assignment of responsibilities and authorities, in vertical and lateral relationships, as well as in the basic management system and management style. In particular, two important issues deserve our special attention.

1. The issue of "independent authority". This refers to the rights of the individual units, departments and systems to make their own decisions. In a socialistic country, the unified planning system doest not preclude independent authority in management, because the latter encourages initiatives at the unit, department and system levels, so that they can fully develop their unique characteristics and potentials, enhance management activities, and improve management efficiency.

Labor associated with scientific activities is different from labor required for p oduction activities. Scientific activities are basically unpredictable and involve many unknown factors, whereas production activities are predictable and routine. The productivity of scientific activities cannot be easily measured as in production activities. With scientific activities, it is important to maintain a flexible policy to encourage the researchers to develop their subjective initiatives; for example, research plans and budgets should not be totally rigid, they should be allowed to change with individual circumstances.

In S & T management, research units should have the following independent authorities: 1) Relative authority for planning. With the exception of planned missions ordered by superior that must be carried out (we call them big plans), the units should be allowed to make their own decisions to implement a number of small plans in accordance with the available manpower, money and materials; the overall plan of the unit should be a combination of the assigned big plans and the unit-initiated small plans. 2) Relative authority for personnel selection. With the exception of the pre-assigned and key leadership personnel that must be approved by the superiors, the unit should have complete authority to recruit its own personnel or even exchange personnel with other organizations. 3) Relative authority in

control of finances. Within the guidelines of state policies, the majority of research units should explore different ways of increasing their revenues in order to enhance the capability to do research and to improve the compensation and benefits for the employees. 4) The units should have independent authority in organization and management in order to better utilize human, financial and material resources, and to increase productivity and the number of trained personnel.

2. The issue of "responsibility system." The responsibility system in modern management has many unique features. The most outstanding feature is the unified management of responsibility, authority and reward. While responsibility comes first, it also specifies the degree of authority and reward that accompany responsibility. Responsibility represents pressure, authority represents power, and reward represents motivation. Without power and motivation, responsibility lacks assurance and incentive. Only by combining all three can responsibility be best achieved.

Therefore, when implementing the responsibility system in S & T management one must pay attention to the following groundrules: 1) the responsibility system in scientific activities must be evaluated in terms of its economic value, its social value and its academic value; 2) within the constraint of meeting productivity and time requirements, the responsibility system should have a certain degree of flexibility; 3) the responsibility system should not be judged by its format, the important issues are its degree of innovation, its research efficiency and its effectiveness in practice; 4) the responsibility system should ensure satisfactory conditions for labor and provide a reasonable formula for rewarding labor.

Of course, complete implementation of independent management authority and the responsibility system must be carried out in parallel with the reform of the overall S & T management system. For example, members of the leadership team should be knowledgeable in the fundamentals of different modern technologies and their relationships; they should understand the principles and methods of modern management and have certain amount of management experience; the organization of S & T personnel should be structure in such a way as to facilitate the execution and implementation of research plans; the management system should be healthy and democratic, and the managers should be subject to constant scrutiny by the public.

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CSO: 4008/174

NATIONAL DEVELOPMENTS

REPRESENTATIVE ATTENDS TECHNOLOGY TRANSFER MEETING

OW171933 Beijing XINHUA in English 1512 GMT 17 Jan 85

[Text] Cairo, 17 January (XINHUA)--A 5-day international conference on transfer of technology to developing countries through their expatriate nationals closed here today.

The participants agreed to step up efforts to stop the "brain drain," the exodus of specialists to developed countries, by bringing skilled expatriates back to their countries of origin for short-term consultancies.

Representatives from 18 countries including China, Egypt, Turkey, Pakistan, India, Greece and Dominica as well as some international organizations participated in the conference.

Bu Zhaomin, director of the International Department of the Chinese Ministry of Foreign Economic Relations and Trade, made a speech at the conference. He presented to the conference China's achievements within the scheme of Toktem (transfer of knowledge through expatriate nationals), which was sponsored in 1977 by the UN Development Program (UNDP).

He said that by the end of 1984, 187 consultancy services of overseas Chinese experts had been implemented within the scheme, which covered industry, agriculture, medicine, urban planning, finance and insurance. These services have contributed to China's economic prosperity and social development, he added.

He said that to meet the needs of its modernization drive, China will try any other possible means to substantially introduce advanced technology and managing methods and to train on a large-scale professional workers.

UNDP figures show that there are now an estimated 400,000 to 500,000 skilled professionals of developing country origin living and working outside their homelands. Many of them have chosen to settle permanently abroad.

The next Tokten conference will be held in China in 1987.

CSO: 4010/69

NATIONAL DEVELOPMENTS

PRC TO PROTECT DOMESTIC, FOREIGN PATENTS

OW261324 Beijing XINHUA in English 1256 GMT 26 Jan 85

[Text] Beijing, 26 January (XINHUA)--China will officially protect the interests of both domestic and foreign inventors when its patent law goes into effect on 1 April, according to Gu Ming, deputy secretary general of the State Council.

The law is first aimed at tapping the resources of China's billion people by protecting and rewarding invention and creation, Gu says in an artilce in the current issue of the communist party theoretical journal, RED FLAG.

Protecting the rights of inventors, whether they are individuals or organizations, will help break egalitarianism and boost the development of economic and technical responsibility systems, he says. The reforms have already yielded satisfactory results in some respects.

While drawing on the experience of other countries, the patent law bases its terms on the country's actual needs and will aid the development of consumer-oriented industries to meet growing public demands, Gu says.

Enlarging the scope for invention will also encourage more people to get involved in technical innovation and the spread of new techniques.

The state's right to spread valuable patents shows that the interests of the state and people come first. At the same time, patent holders can charge fees for use, so their creative enthusiasm will not be dampened and their interests now encroached upon.

Promulgation and implementation of the patent law will also promote technical exchanges with other countries, Gu says. China has economic ties with more than 160 countries.

Since the patent law provides for adherence to common rules and regulations as required by trade and international economic relations, it will facilitate the import of advanced techno) gy by protecting foreign patents from plagarism or unauthorized transfer, Gu stresses.

On the other hand, China's patent rights also need international protection, and this added security will further promote technical exchanges with other countries on equal terms, Gu says.

China has imported large quantities of motor vehicles, machines and equipment in the past 3 decades, but has not paid enough attention to importing patents, Gu says.

To help narrow the technological gap between China and the economically developed countries, China should purchase more patents when importing equipment or products in the years to come, he says.

CSO: 4010/69

NATIONAL DEVELOPMENTS

DEVELOPMENT OF POTENTIAL OF RETURNED STUDENTS URGED

Beijing GUANGMING RIBAO in Chinese 25 Nov 84 p 1

[Article by Zheng Haining [6774 3189 1380]]

[Text] To the Editor's Office:

The China Scientific and Technical Association recently organized local scientific associations in 15 provinces and cities including Beijing, Tianjin, Shanghai, Guangdong, Shanxi, Jiangsu, Zhejiang, Anhui, and Sichuan. They conducted extensive panel discussions, home visits and written surveys for over 4000 scientific and technical students who had studied abroad and returned home since 1978. The results show that many returned scientific and technical personnel have been active in making contributions in their field, but a significant number of them have not been able to develop their potential.

The main factors limiting the development of the full potential of retirned scientific and technical personnel can be summarized as follows:

1. Some leaders lack a good understanding of the capabilities of scientific and technical personnel; policies for treating intellectuals have not been implemented at some organizations. Many organizations have made no serious effort to match the background of S & T personnel with jobs in leadership positions, production technology or research facilities; they have the simple view that implementation of policies for intellectuals consists of merely finding assignments for a few S & T personnel. As a consequence, many S & T personnel who had been promoted to leadership positions could not perform their functions effectively. As on engineer pointed out, before going abroad he had a technical job in the factory, but upon returning he was assigned an administrative position in which he had no opportunity to develop his special skills. In other organizations, there are rigid seniority systems that prevent returning young S & T graduates from assuming responsible positions. A small number of organizations still have prejudice against S & T personnel, who are often subject to oppression and attack.

2. The existing S & T management system is so inhibitive that it is difficult for returned S & T personnel to develop their potential. S & T personnel are dissatisfied with the existing job system, personnel system, and economic distribution system. The main complaint is the lack of authority in making

decisions concerning research activitiqs and personnel affairs. In a survey of 52 returned S & T personnel conducted by the Tianjin Scientific and Technical Association, 24 indicated that their ability to make positive contributions is adversely affected due to the lack of independent authority.

3. The necessary experimental conditions are absent. Comments by S & T personnel indicate that some organizations wasted large amounts of research funds by importing useless instruments and equipment, and therefore have no funds to purchase urgently needed experimental equipment to carry out the planned research projects. Another factor which limits the effectiveness of S & T personnel is poor support service. A university associate professor who returned in 1982 after studying abroad spent one and half years trying to get funds for research equipment. After the funds were approved, he had to personally deal with the details of procurement and processing so that today, no progress has been made in the research project.

3012
CSO: 4008/174

NATIONAL DEVELOPMENTS

BRIEFS

PATENT LAW ADDRESSES INVENTOR'S RIGHTS--Beijing, 25 January (XINHUA)--The principle of the patent right belonging to the inventor will be followed when the Chinese patent law officially goes into force on 1 April. Huang Kunyi, director of the National Patent Office, said this at a press conference here today. Inventors are entitled to receive awards from their units, as well as profits accruing from the application and transfer of their inventions, he added. Huang's office will officially handle patent applications from 1 April. [Text] [Beijing XINHUA in English 1842 GMT 25 Jan 85 OW]

CSO: 4010/69

APPLIED SCIENCES

DEVELOPMENT OF CHINA'S STANDARDIZATION PROGRAM

Beijing ZHONGGUO BIAOZHUNHUA [CHINA STANDARDIZATION] in Chinese No 10, 1984 pp 1-6

[Article prepared by the Chinese Bureau of Standards: "Developments in China's Standardization Program in the Past 35 Years"]

[Text] Standardization is an important means to organizing modern production, a vital component in scientific management and a fundamental task in the nation's economy. In socialist modernization, standardization has an important effect on accelerating the growth of the economy, improving the quality of products and engineering projects, encouraging technological advancement, increasing economic benefits, and realizing modern management systems. As international exchange in economy and technology becomes more active, standardization has already gone beyond the border of a nation. It is becoming international.

The old China was a semi-colonial, semi-feudal society with a poor economy and outdated technology. Although the Nationalist government had a standardization organization, however, the work was not actually carried out.

After the new government was established, the Communist Party and the government had devoted attention to the establishment and development of China's own standardization program. In the past 35 years, the standardization program in China has grown rapidly. Presently, standardization offices are established all over China. Large and medium-sized enterprises and engineering construction units are also equipped with special mechanisms and personnel to undertake the task of standardization and quality inspection. By the end of 1983, the standardization team was expanded to over 12,000 people (not including the business sector). The government issued 5,494 national standards for industrial and agricultural products, engineering construction, environmental protection, safety and hygiene and scientific management. The State Council and its various departments issued more than 13,000 ministry level standards. Various provinces, autonomous regions, and directly governed cities issued more than 89,000 industrial standards. These standards effectively promoted economic growth.

I

Since the founding of the socialist country, the standardization program in China has changed from a scattered to a centralized system. The program has evolved from adopting foreign systems to incorporating Chinese characteristics. After the 3 Plenary Session of the 11 party Central Committee, the program entered a development stage.

In the early stage, the government's standardization work was primarily focused on economic recovery. In response to the needs in manufacturing and export involving private businesses, various economic departments formulated and issued some inspection standards for import and export goods. In the first 5-year Plan period, major industrial departments began to establish organizations to strengthen the guidance and control of the standardization work. For example, the Ministry of Petroleum Industry established the "National Review Committee on Specifications of Petroleum Products" and issued the first batch of standards for testing petroleum products. The Ministry of Heavy Industry appointed the Institute of Construction Material Science as the national testing organization for cement standards; responsible for comparative and arbitrative testing of cement. The Ministry of Metallurgical Industry published 214 standards and the Ministry of No 1 Machine-Building Industry issued basic standards for mechanical drawings and tolerances. The electronic trade published a number of standard elements. The drafting and execution of these standards improved the technologies, strengthened the management, and upgraded the quality of products. In the 12-year Scientific and Technological Development Plan prepared by the Science Planning Committee of the State Council in 1956, the formulation and execution of unified and advanced national technical standards was identified a necessary measure in a rapidly growing economy. In the same year, the central government decided to put the National Technical Commission in charge of the national standardization work. Moreover, the Bureau of Standards was established within the commission. Since then, the standardization work in China was centralized and national standards began to be drafted. By the end of 1958, there were 124 national standards. At the same time, relevant ministries in the State Council also issued some ministrial standards. However, the standardization work was seriously hampered by the "leftist" ideology. In January 1961, the central government set the policy of "adjust, reinforce, solidity and improve". In December 1962, the State Council issued the "Regulations for Managing Technical Standards for Industrial and Agricultural Products and Engineering Construction". In the Spring of 1963, the State Science Commission held the first national standardization meeting and drafted a 10-year standardization plan for 1963-1972. The plan was aimed at the establishment of a comprehensive standardization system using the national standards as core. It should suit the resources and natural conditions in China and fully reflect the advanced production technological level. After the meeting, relevant departments in the State Council formulated their own standardization development plans. The State Science Commission established the

Comprehensive Research Institute of Standardization and the Publishing Company of Technical Standards. It officially appointed 32 research institutes and design units as the first batch of leading technical standardization organizations. The relevant departments in the State Council also appointed a number of research institutes, plants and mines as the leading organizations of technical standardization for various departments to be responsible for the research in standardization and the formulation and modification of standards. In the 5-year adjustment period the standardization work was enforced and the pace of formulating standards was accelerated, which promoted the improvement of the national economy.

During the "Cultural Revolution" period, because of the influence of the wrong leftist ideology, standardization work was in difficulty.

After the "gang of four" was crushed, the standardization was quickly restored. In 1978, the technical standards in China were thoroughly reviewed and reorganized. On the basis fo the "Regulations to Manage Technical Standards for Industrial and Agricultural Products and Engineering Construction", we began to discuss and draft the "Standardization Regulations in People's Republic of China". In May 1978, the Communist Party Central and the State Council approved the establishment of the National General Bureau of Standards (changed to National Bureau of Standards in 1982). It is directly under the jurisdiction of the State Council and operated by the National Economic Commission to solve the problems encountered in standardization and to create more favorable conditions for production and service.

II

Since the 3d Plenary Session of the 11 party Central Committee, the economic policy of "adjustment, restructuring, consolidation and improvement" has been thoroughly executed in standardization. A series of major policies of the central government, such as the promotion of technological advancement, improvement of the economy both foreign as well as domestic was carried out. We are entering a new era. In March 1979, with the approval of the State Council, the National Bureau of Standards held the second national standardization workshop to summarize our experience. The duties in the adjustment period and the policy of "strengthening management, thorough reorganization, establishing good foundation and enthusiastic development" were made public. In July, the State Council issued the "Regulations to Manage Standardization in People's Republic of China". In the past 5 years, standardization has been centered around the adjustment of the national economy to actively serve economic development and has obtained significant results.

(1) Management Structure and Organization in Standardization Strengthened, Preparation of Standards Accelerated Currently, various level of government established their own organizations to manage standardization, responsible for their standardization and quality inspection work.

The system to formulate and revise standards and to conduct research was gradually established. The construction of the Chinese Standardization Research Institute of the National Bureau of Standards resumed in 1979. There are 15 departments in the State Council with research institutes of standardization. There are more than 300 leading technical organizations and over 30 technical standardization committees for various trades. In engineering construction, design, construction and research units a number of groups were set to control standards and specifications. In 1979-1983, 3,978 national standards were formulated. A number of them, such as "Structural Steel for Ship Building" and "Twist Drill", are on the world level. The standard of "Fundamental Collection of Symbols for Coding Chinese Characters in Information Exchange" received a lot of attention from the "International Standardization Organization" as well as from many countries. A number of important projects in the scientific research of standardization, such as the chart of the Chinese standardization system and the evaluation principles and computation methods of the effect of standardization on the economy, were completed. A great deal of research on the standardization of engineering and construction was also initiated. Some accomplishments have already been certified and applied on a trial basis.

We have also made great progress in publishing standards as well as related information and data. The Information Center of Standards in the Chinese Research Institute of Standardization has collected 350,000 pieces of information in order to provide service for the inquiries from various fields. In 1983, it received readers for more than 20,000 times, and supplied and reproduced over 120,000 documents. It has a preliminary national information network of standards with 27 existing information centers of standards in various provinces, autonomous regions, cities and departments. Chinese Publishing Company of Standards has an annual printing capacity of 50 million words. Standards are distributed via numerous conduits. Xinhua Bookstore has already opened stores, departments or counters for technical standards in 17 cities. China Publishing Company of Standards and some local standardization organizations also directly supplied certain users.

In 5 years, a large number of people in standardization were educated. All the directors of the Bureau of Standards in provinces, autonomous regions, directly governed cities and major industrial cities have been trained. Standardization and quality inspection training centers were set up in Liaoning and Fujian. Training bases were established in some higher learning institutions. Various departments and localities have held different types of training classes of standardization and quality inspection. In 1983 alone, on the level of the 23 provinces, autonomous regions and cities, 146 study classes were held, involving 21,000 people. The technical and professional level of standardization professionals was improved. Presently, a national standardization team has been formed.

(2) Product Quality Assurance Widely Implemented

The National Bureau of Standards established the Product Quality Monitoring Bureau in 1979 and various local standardization departments also set up corresponding quality monitoring outfits. Inspection of product quality is an important component of standardization. Throughout China, we have widely implemented a strict third party inspection system to monitor product quality according to standards. More than 140 monitoring and inspection centers have been restored and established by various standardization departments and over 1,200 inspection stations were built. They cover more than 100 cities and the products to be inspected involve more than 25,000 businesses. More than 60 inspection centers (stations) were established throughout China by light industries, electronic industries, construction material industries, posts and telecommunications office, and public safety departments to form a preliminary product quality inspection network.

Over the past 5 years, product quality inspection organizations intensified scheduled and unscheduled inspections on key products and products closely related to the welfare of the people as well as to safety and hygiene. They also perform tests upon the request of production units and participate in the ranking of high quality products. In addition, they are responsible for registering trademarks, certifying new products and arbitrating disputes. They have enthusiastically participated in the "quality month" activities since 1979 and engaged in the selection of high quality products. Since 1981, they began to demonstrate the quality of certain electronic products.

(3) Advanced International Standards Adopted to Raise Chinese Standards

Most of the present Chinese standards are equivalent to the international level in the 1950's and 1960's. In recent years, we have accelerated the adoption of advanced international standards based on the situations in China according to the policy of "serious research, active adoption and differential treatment". It has a significant effect on technological advancement, product quality and economic benefit improvement, and foreign trade expansion. China Ship Building Corporation formulated 289 foreign trade standards based on advanced international standards to improve the degree of self-sufficiency in ship construction, which saved foreign exchange and promoted the export of ships. The paper making trade adopted 36 international standards. In newspapers alone, 70,000 cubic meters of lumber can be saved nationwide. The Ministry of Machine Building adopted international standards for 880 electrical products directly under its jurisdiction. Among them, medium and small electric motors produced by Shanghai Yaojin Electric Plant, welding strips made by Tianjin Welding Strip Plant, and butterfly valves manufactured by Tanggu Valve Plant are competitive in the international market. The ratio of advanced international standards in the Chinese standards formulated in 1983 was increased from 25 to 30 percent. The level of Chinese Standards was pushed forward.

(4) New Progress Made in Local and Industrial Standardization

Local standardization has been carried out on the basis of a very weak foundation. As we worked with difficulties, we also built up the system. A large number of local industrial standards were drafted in recent years and the situation was significantly improved. Standardization work was launched in many areas by taking the local characteristics into account. For instance, agricultural standardization was developed in Jiangxi, Hubei, Sichuan and Helongjiang. The standardization of seeds could usually increase the crops by 10 percent and save seeds by 3-5 percent. Shanghai took advantage of its technical capability to enter the international market. It set the key standards for high quality products for export. Liaoning, Jiangsu and Shandong standardized energy conservation to deal with their high energy consumption and energy shortage problem. Inner Mongolia and Xinjiang enthusiastically implemented wool standards, thus contributing to the development of light textile industries. The standardization departments have also obtained new accomplishments in promoting and implementing national standards, performing product quality inspection, reviewing standards for new products, training new personnel, and providing information on standards.

Business stanardization, which is the foundation of business management, has received more and more attention from the leadership. It has been actively developed in recent years. Some enterprises proposed to "obtain quality and benefit through standardization." Many enterprises reorganized and strengthened their standardization work, and established and perfected their standardization systems. They fortified the organization and personnel. In some cases, a stanardization committee consisting of the plant manager and responsible people of various offices and shops are created to study major problems and to organize the work in standardization. The scope of the work is extended beyond technical areas to production and management. There are technical standards as well as management standards. A business is no longer limited to the implementation of national and ministrial standards. Instead, they draft and implement trade standards which are higher than existing standards based on export or user requirements or on the needs to excel. The standardization work is performed closely with business management, quality ontrol, technological reform and implementation of an economic responsibility system, which improves the quality and profit of the business.

(5) International Standardization Activities Participated, Exchange Enhanced

China joined two major international standardization organizations - the International Electric Commission (IEC) and International Standardization Organization (ISO) in 1957 and 1978, respectively. Furthermore, we were elected as a member of the executive committee and board of directors in 1980 and 1982, respectively. As an active member, China is involved in 80 technical committees and 247 technical subcommittees in the

International Electric Commission. In the past 5 years, 947 Chinese experts attended technical workshops in these two organizations. Since 1979, China also searched mutual agreements with Federal Republic of Germany, France, U.S., England, Sweden and Canada. Moreover, it also established an information exchange system with 29 nations and received over 7,100 international standards in the past 5 years.

(6) Fast Progress Made by Standardization Society, Publicity of Standardization Extensive

In July 1979, the Chinese Standardization Society held its first membership meeting, marking the extensiveness of standardization in China. There are 26 provinces, autonomous regions and cities which established standardization societies. There are 15,000 members nationwide. The society was involved in the academic exchange of standardization in order to publicize it. In the past 5 years, China Standardization Society held 31 academic exchange meetings and presented 645 papers. It organized the writing and publishing of 20 books for over 300,000 volumes to popularize standardization. It also publishes over 30 journals, among them the monthly magazines "Chinese Standardization" and "Status of Foreign Standardization" are exchanged among more than 20 countries. It made 12 movie and video pictures to promote and improve people's understanding about standardization.

(7) Marching Towards New Territories

In recent years, the scope of standardization in China has been expanded into environmental protection, atomic energy utilization, energy conservation, information processing, statistical management of the economy and document management. Furthermore, a number of standards must be drafted and implemented to promote the exploitation of new technologies and modern management techniques.

III

For 35 years, standardization has had an important effect on the promotion of economic growth, technological advancement and modern management in China.

(1) Quality Control Favored, Product Quality Improved

Since the overall review and reorganization of standards in 1978, standards were set for products without them. Outdated standards were revised. For example, the nitrogen content of agricultural ammonium bicarbonate used to be low. The product would easily agglomerate and suffered serious losses. The standard was revised in 1981 to increase the nitrogen content and to lower the water content. Ammonium bicarbonate no longer agglomerates. Not only the quality of the product was raised, but also the loss suffered from manual crushing in the field is reduced. It brings a great deal of economic benefits

to the farmers and the country. Revised national standards for cotton yarn, cloth and printing and dying increased the strength of cotton yarn and the homogenuity of patterns, which basically met the export and user requirements. Since the implementation of the wheat standard in 1979, more than 85 percent of the wheat purchased is above the medium quality. The farmers' income is increased, which also gives them incentive to produce and sell high quality wheat.

(2) Favoring Specialized Production, Increasing Productivity and Conserving Raw Materials

A variety of types and specifications of fasteners such as screws, nuts, bolts and washers were used in large quantities in electrical and mechanical products. They were used in large qualities in electrical and mechanical products. They were produced in small batches and were not suited for specialized production. Each major plant used to make their own. The productivity was low, the quality was poor, and the consumption of raw materials was high. Since 1985, the standards were revised three times to simplify and unify more than 700 specifications to around 200. Specialized production was organized in each region, resulting in very ovious economic benefits. After the national standard for size number of clothe was released, apparals were produced in large quantity by specialized organizations. This not only increased productivity, but also makes it easy for the consumers when they make their purchases in different areas. Moreover, when 100 million clothes are manufactured, by mass production, it is possible to save 50 million feet of materials which can be used to make 6-7 million more clothes.

(3) Rationally Utilizing Resources and Conserving Energy

The drafting of a product standard must be scientifically experimented. It must be demonstrated from various aspects and be determined based on the resources in China. For example, through a great deal of scientific research and practical tests, the cement standard was revised so that the magnesium oxide content in mixed cement should not be greater than 5 percent. This not only would not affect the engineering quality but also can extend the limestone to fully utilize the resources and to conserve the investment. As another example, after implementing the national standard of "Low Pressure Boiler Water Quality," water scaling was reduced and the total output of boilers increased by 30 percent. More than 4 million tons of coal can be saved for small and medium-sized boilers alone. In recent years, some energy management standards were also formulated to conserve energy.

(4) Benefiting from Application of Research Accomplishments, Promoting Technological Reform, Improving Technical Standard

Because new scientific research accomplishments were included in standards as they were drafted, these accomplishments could be rapidly applied

through the implementation of these standards. They will become new productivities and improve the technical level. The twist drill and pre-stressed concrete are typical examples.

(5) Promoting Foreign Trade, Improving Competitiveness of Chinese Products in International Market

In recent years, most of our standards were drafted in order to improve the quality of products. We actively adopted international standards to enhance the competitiveness of our products in the market. The newly formulated national standard for ship building steel satisfied the needs in building ships for export. It created favorable conditions for us to export ships. Since the drafting and implementation of the national industrial furfural standard, the quality reached top grade level. Some products are of superior quality. The export volume is on the top of the list in the world.

(6) Protecting the Environment and Securing People's Safety and Hygiene

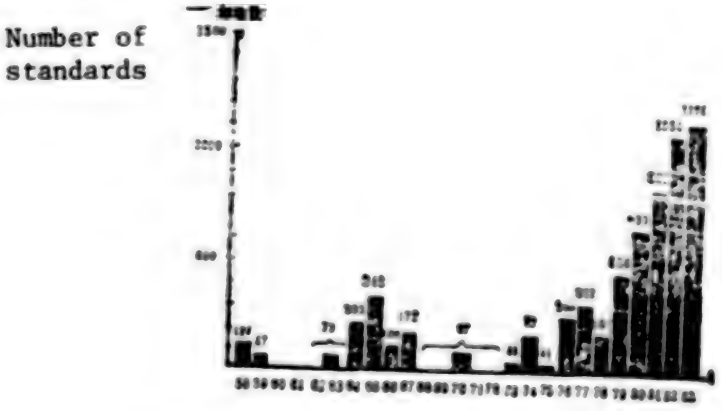
Environmental protection, prevention and elimination of pollution, and solving safety and hygiene problems in production and everyday living is an important task of standardization. China issued various standards such as "Trial Standards for the Release of Wastes in People's Republic of China", "Safety Standards for the Application of Pesticides," "Atmospheric Quality Standard", "Environmental Noise Standard in Urban Areas" and "Standard for Food Hygiene." The implementation of these standards controlled or alleviated the pollution in some key protection cities, pesticide incidents and poisoning were greatly reduced. A series of standards was also drafted and implemented in labor protection and electrical safety to protect people's health and safety.

(7) Providing Basis for Modern Management

The storage and processing of information in a computerized automatic management system as well as the exchange of information among various departments will require a unified language. In recent years, China has drafted standards such as "Codes for Administrative Regions in People's Republic of China," "Human Sex Code," "Standard for Classification of Economic Trades," "Standard for Job Classification" and "Basic Collection of Chinese Character Codes for Information Processing and Exchange." They have already built an important foundation of modern management through the third national census in 1982 and other economic statistics.

In the past 35 years, standardization in China had many ups and downs. If we have the correct guiding ideology, respect science and technology, and focus on product quality and economic benefit, then the standardization work can be developed in a rapid and healthy manner. If not, the standardization work will be hindered. This is fully reflected in the formulation of national standards in China (see figure). Through

practice, we must thoroughly implement the policy of promoting technical progress and improving economic benefit. It must be closely linked to economic growth and should actively serve the economy. A great deal of research is required when standards are drafted. A standard must be built on scientific basis. We must work hard to convert scientific research results to productivity and build a strong professional team to build up the business. Although we have obtained great results in standardization, it is still a weak link in the economy due to its poor foundation. In order to satisfy the needs in modernization and foreign exposure, especially in technological revolution, we must reform and accelerate to catch up in standardization by taking effective measures. We must work hard to lay down a strong foundation in the 1980's and build a Chinese style standardization work system in the 1990's in order to contribute more to the economic growth in China.



Number of standards issued over the years.

12553

CSO: 4008/79

APPLIED SCIENCES

PRC ANTARCTIC TEAM STUDIES MICROORGANISMS

OW261702 Beijing XINHUA in English 1625 GMT 26 Jan 85

[Text] Aboard S.S. Xiangyanghong 10, George Island, January 25 (XINHUA)--The Chinese expedition team have found some rare kinds of fungi for the first time in the Antarctic.

Microbiologists on the team have made 226 experiments on samples derived from ocean waters, soil, melted snow and living krills. They selected eight mediums which are being cultured at three different temperatures, and succeeded in separating large quantities of fungi to be taken home for further study.

Cryophilic fungi obtained ranged from heterophrophic, saecharo and filiform fungi.

Experts said that in the South Pole bacteria, particularly contagious ones, are rare whether in waters, on land or in the atmosphere. There are about a dozen bacteria in every milliliter of waters in the upper part of the Maxwelleay Gulf off the George Island, and no bacteria have been found in seabed soil ten centimeters deep, they said.

Study of Antarctic microorganism forms an indispensable link in the knowledge about Antarctica concerning energy mobility and material circulation. Experts believe that most of the fungi discovered in brooks of melted snow comes from birds roosting here, and human activities may also bring pollution in the South Pole.

CSO: 4010/70

APPLIED SCIENCES

LASER APPLICATIONS IN LAST 10 YEARS REVIEWED

Shanghai ZHONGGUO JIGUANG [CHINESE JOURNAL OF LASERS] in Chinese No 10, 20 Oct 84 pp 577-583

[Article by Lu Zhiguo [7120 3112 0948]: "Progress in Laser Applications in China in Past 10 Years"]

[Text] Abstract

This paper is a survey of the progress of laser applications in China in the past 10 years (1974-1984) in industry, holography information processing, instrumentation and other scientific research.

The CHINESE JOURNAL OF LASERS was established 10 years ago. In these 10 years numerous laser applications have been developed. If we were ignorantly optimistic about the development of laser application 10 years ago, the work over the last 10 years has certainly been very solid and careful. Many experimental prototypes have moved toward production, many practical problems have been solved and extensive experience has been accumulated on applied research. A solid foundation has been established in the technological revolution of laser application. In this article we review the progress of laser applications in China in the past 10 years.

I. Industrial Applications

Laser machining is an area in laser application that was developed first and has had the most impact on industrial applications of lasers. In the mid 1970's, lasers were first used for hole drilling in gemstones. The test production period lasted almost 10 years and it is only in the last few years that the technique has become economically attractive. Using YAG lasers for rapid hole drilling the quality and quantity are much better than the neodymium lasers used 10 years ago and the efficiency has been improved by almost 12 fold.[1] In the past only small holes could be made by laser but today the technology has matured for both large size holes and for millipores. On stainless steel plates, millipores of 0.015 mm diameters may be drilled.[2]

Laser pulse modulated hole punching technology has been developed. Using Nd-doped glass laser and YAG laser, the free oscillations were made to resonate

in the cavity using ultrasonic vibrating mirror, acoustooptic modulator or color center absorption saturation and to produce periodic loss so the laser output has a series of peaks. This pulsed laser hole punching technique has greatly improved the accuracy, surface quality and duty cycle of the process.[3]

Laser welding[4] in the first 10 years of laser development was limited to microspot welding. In the last decade, because of the improved power output of CW CO_2 lasers, seam welding was also made possible.[5] Most of the laser welding in China today is pulsed welding, which has had wide applications in the electronics industry and has solved a number of difficult technical problems in the watchmaking industry.

Using a multi-mode 100W sealed CO_2 laser welder, continuous welds may be made on 0.5 mm steel alloys and some equipment and meter components.[6] Further studies showed that materials of similar properties should be used in sealed welding and metals with a high thermal conductivity should be heat treated first. Laser power, pulse width, repetition rate, and spot overlapping must all be held to a close tolerance.

There are two mechanisms in laser cutting. In one method the cutting is achieved with the aid of an auxiliary gas which removes the melted material from the reaction zone of a focused laser. This method is used for the cutting of metals. In the other method the material is fractured under thermal stress caused by the focused laser. This method is used in the cutting of brittle materials such as ceramics. In 1977, digitally controlled 500W CO_2 laser cutters were used in the cutting of steel plates[7], recently lasers are also used in the inscribing of textile printing barrel and in the cutting of the teletype color bar.[8]

Along with the development of kilowatt CW CO_2 lasers, heat treatment using laser has been actively studied. The hardness can be increased by 15-20 percent when laser quenching is used instead of conventional quenching. The hardness of low carbon steel, which is difficult to heat treat using conventional quenching, can be much improved with laser heat treatment. Studies of several carbon steels have shown that the quenched structure is martensitic but the size is small. The martensite in the completely quenched and incompletely quenched regions are extremely small. This explains the high hardness and the tough and yet not brittle nature of the laser quenched material.[9]

Theoretical analysis[10] shows that, when a metal surface is illuminated by laser light, part of the energy is reflected and part enters the metal. Most of the energy entering the interior of the metal is absorbed by the electrons and converted into thermal vibration of the crystal lattice. The spreading of the energy is governed by the thermal conduction process. When the metal surface absorbs the laser energy, a "hot layer" is formed. This hot layer has a formation time much shorter than the laser irradiation time and a thickness far less than the hardening thickness. The hot layer is the heat source of laser heat treatment. Except in the hot layer, the temperature in the interior of the metal is determined by the thermal conductivity.

Laser heat treatment is applied not only to metals but also to materials used in the electronics industry. Ion implanted photodiodes have an enhanced blue light sensitivity when annealed with CW CO_2 laser. Analysis has also been made for the CO_2 laser annealing of As^+ implanted Si. Solar cells have been made using laser induced diffusion.[11]

Laser applications in the electronics industry is the most promising area in laser application. In addition to the applications described above, holography has also been used in the fabrication of photoetching mask; in chemical vapor deposition laser has been used in the preheating of the silicon substrate; laser GaAs; and resistance regulation has been made with acousto-optic Q-switched YAG laser.

II. Holography and Optical Signal Processing

Experimental studies of laser holography were conducted in China in the first 10 years and extensive applications were made in the last 10 years. Deformation displacement measurement using double exposure holography was used in the determination of the stress distribution. The method has been widely used in the stress distribution measurement of blades, circular plates, and square plates in the thermal deformation measurement of engine pistons, index of refraction distribution in transparent material, in the nondestructive evaluation of honeycomb structures and documents, and in the study of the vibration modes of buildings. The technique of nondestructive testing of tires using holography has gained maturity[12,13], the technique is especially useful in the detection of delamination of the interior of the tires. Holograms of a 1.6m high, 1.1m wide milling machine were analyzed in a microprocessor to obtain the three-dimensional displacements of the machine.[14] Holographic interferometry has also been successfully applied to the stress measurement of photoelasticity and the flow fields in a wind tunnel.

Holographic microscopy is especially useful in medicine and biology as it may record the three dimensional activities of biological bodies. Good results[15] were obtained in a series of holographic microscopic studies of diatoms, and other protozoa and organisms as early as 1976.

The maximum angle of view is 180 degrees for the recording and reconstruction of ordinary planar holograms. To increase the view angle and enhance the 3D effects, wide angle holography was developed. Stepwise recording of wide angle polygon hologram and slit-masking wide angle hologram have been used.[16]

Using a multipulse ruby laser as a light source, 11 consecutive holograms were recorded in 1978. High-speed holography[17] may be used in the recording of the instantaneous state of motion of fast moving objects.

A number of new methods have been developed for colored holography. For example, the object may be photographed in the three primary colors and recorded respectively on the film in the form of black and white positives and the images are then recorded on three long strips of holograms. When the three holograms are illuminated with monochromatic conjugate light waves, the three reconstructed images overlap in space. A holographic film is then used to

record the three real images containing the signals of the three primary colors to form the colored hologram.[18] An important technique in three dimensional colored display is the recording of the colored hologram using the Lipman method and then display the image using white light. Although the ordinary photographic emulsion containing silver salt has good sensitivity, its noise figure and diffraction efficiency are not as good as that of dichromate gelatin and the latter gives a better image quality and brightness. Using methylene blue dye as a sensitizer, the photosensitive range of dichromate gelatin may be extended into the red region and 84 percent of diffraction efficiency has been obtained in holographic diffraction gratings[19] photographed with a He-Ne laser.

Computer generated holograms may provide any wavefront that is needed and they have been used in the inspection of nonspherical mirrors.[20] The phasogram is a phase reconstruction device similar to computer generated hologram. It does not require a reference beam and records the phase of the light wave under the assumption that the wave amplitude in the entire recording plane is a constant. Phasograms are generated by a computer and are especially useful in displaying mathematical objects in three dimension. Although the reconstruction of a phasogram is similar to that of a coaxial hologram, the phasogram reconstruction may be free from conjugate interference and, with accurate phase matching, the reconstruction efficiency can be very high and can be done with ordinary light sources.

The liquid surface ultrasonic holography technique provides dynamic image of the interior structure of objects in real time with superior fidelity and resolution. Focused liquid surface hologram using pulsed ultrasound has been used in obtaining clear images of a live carp and the palm and arm of an adult. Not only are the ulna, the radius, and the finger and palm bones clearly visible, some of the soft tissue invisible under X-rays can also be seen.[21] In addition, nondestructive inspection of the interior of objects has also been made.

In laser holography, speckles not only degrade the resolution of the reconstructed image but also contribute to the background noise. However, the development of speckle interferometry has found wide applications of the speckle phenomenon in the measurements of displacement and stress. Laser specklegraph is especially useful in the measurement of the displacement component in the plane perpendicular to the observation direction. Speckle interferometry may supplement holographic measurements. For example, when a double exposure phase plane hologram is used in the determination of the minute 3D displacements of an object, the out-of-plane displacement may be measured using the ordinary double exposure holographic interference method whereas the in-plane displacement may be obtained by an optical Fourier transform of the speckle pattern superimposed on the hologram.[22] In addition, laser speckles are also used in the measurements of other parameters in mechanics such as the out-of-plane displacement, angular displacement and vibration.[23]

The amount of information contained in a hologram depends on the recording mode. The maximum signal content is equal to $(c/d)^2 \log R$ where c is the size of the film, d is the resolution and R is the dynamic range of the film. The

resolving power of type I(6328 Å) and type II (6943 Å) holographic plates is 2800-3000 lines per millimeter.[24] In addition, photoconductive plastic and organic free substrates have also been developed.[25]

The reverse filter is an important device for achieving the division operation in graphic processing. Restoration of blurred images and X-ray coded apertures imaging are of special interest. A new reverse filter principle and experimental technique[26] shows that reverse filtering using holography is better than the sandwich method.

In order to achieve the best fidelity and resolution, spatial filters used in removing the fuzziness of images should have the largest dynamic range possible. On the basis of the high-efficiency, wide dynamic range spatial filter using holographic method proposed by S.I. Ragnorsson, the dynamic range of filters has been further expanded using synthetic holography. This method has been successfully used in the processing of out-of-focus pictures.[27] Nonlinear composite holographic diffraction gratings may also be used as differential filters.[28] Optical differentiation is not only an important optical mathematical operation, but also an important means in identifying an object and extracting its profile.

In the processing of holographically coded white light images, it has been proposed that rectangular apertures at different orientation be used in the modulation of the laser speckle to replace the coding by a diffraction grating.[29] It has also been proposed that the laser hologram be used in the coding of the image to achieve the various operations in the white light coding plates, a formula for computing the optimum reference beam angle was derived. In addition, the noise performance[30] of an optical signal processing system has also been studied in terms of the spatial and temporal coherent illumination.

A new nonbleaching type phase hologram has been used in the storage of texts and graphics, including the recording, duplication and display of high density holographic data. In a speckle area of 1 mm diameter, information on 1-2 pages of 8 inch by 12 inch size may be stored. The reconstructed image has good quality and free from speckle noise. The printing of the hologram may be made on No 135 photographic films with Fourier transform and it may also be directly copied electrostatically.[31]

In underground survey it is necessary to analyze a great amount of seismic recordings and geological rock stratum cross-section data obtained in geophysical survey. Using a coherent optical signal processing system based on Fourier optics, the noise on the seismic records may be filtered out and useful information extracted. The method may improve the contrast of rock stratum cross-sections and clearly reveal the cross-sectional structures. Optical signal processing is more economical and faster than computer processing, it is especially useful in the processing of large amounts of seismic records and satellite photos.[32]

III. Laser Applications

Based on the unique characteristics of laser light, a number of laser equipments have been developed and widely used in a variety of professions. A good fraction of these equipments are testing equipments.

Laser interferometric distance meter is one of the earliest laser equipments. In the development of the frequency stabilization technique, it is expected that a unified space and time measurement standard may soon be established. In the last 10 years, length standards of various precision have been established; more important, high precision on-site distance measurements have begun.

The distance may be measured using pulsed laser or using phase of the laser light. Extensive work has been done 10 years ago and the technique of distance measurement by laser is rapidly approaching maturity. Considerable improvements have been made in recent years to improve the accuracy and reliability, to decrease the weight and volume of the distance meter and to expand the scope of applications. Using a 45 degree cut $LiNbO_3$ crystal Q-switched YAG laser, the maximum measurable distance is 5000 m and the accuracy is 0.5 m[33]. Lasers made of a low threshold high efficiency NbP_5O_{14} crystal weigh only 23 grams and can measure 60-3000 m with an accuracy of 2.5 m, they will greatly reduce the weight of the distance meter. Distance measurement using the phase of the laser has been widely used in geodetic surveying. The model DC30JG gas laser distance meter[34] has a range of 15 m to 30 km and an accuracy of $\pm$ 5 mm + 0.8×10^{-6}D, where D is the distance to be measured. Laser distance meters are not only in demand in geological survey and prospecting, but can also be used in the measurement of ocean waves.

Laser velocimeters are generally based on the Doppler effect. In a double-scattering laser velocimeter[35], two beams of He-Ne laser light are focused on the region of interest and, when a gas or fluid flows through this region, the frequency difference of the scattered light and the incident light is directly proportional to the velocity of the fluid. The measurable velocity ranges from 3 mm/s to 300 m/s and the accuracy is 1 percent. Velocimeters based on a CO_2 laser may be used in the dynamic study of vehicles, vessels and other moving targets[36], as well as in the velocity measurement in wind tunnels. Another laser system using an acousto-optic modulator as a frequency shifting device has been used successfully in the measurement of the 2D spatial distribution of the average velocity, turbulence and velocity probability function of the high turbulence backflow in a step expansion tube.[37] To measure the velocity of a high speed target accelerated by a high power laser or a shock wave, a spectrometer is formed using a dye Q-switched ruby laser stimulated by a dual discharge pulse and an etalon. The flight speed of a composite target[38] may be measured at a distance of 250 meters.

Using the good coherence properties of lasers, a number of laser interferometers have been developed. Spherical wave interferometer[39] using a He-Ne laser was developed in 1974. It was used to measure the perfection of aluminum coated and uncoated concave spherical mirrors in a noncontact mode. With the aid of an auxiliary lens, the device was used in the inspection of the

homogeneity of nonspherical media (optical glasses) of an astronomical telescope. It was also used to assess the quality and assembly deformation of optical systems. With the addition of a standard scale and a guiding rail, the device may also measure the radius of curvature of concave spherical surfaces and the spherical aberration of the objective at the He-Ne laser wavelength. The model CLS-95 planar laser interferometer[40] is based on the principle of constant thickness interference. The accuracy in flatness measurement is better than $\lambda/15$ and the accuracy in parallelism measurement is better than 1 second of angle.

Single plate, double plate and Talbot shear interferometers have all been developed and used in the measurement of the laser beam wavefront and coherence length and in the inspection of prisms and lenses.[41-44]

The superior directionality laser has been used in the development of collimators and pointers received wide uses.

Modestly collimated light beams may be obtained by suppressing the divergence angle with a telescope system. Such systems may be used in the construction of mineshafts, tunnels and bridges and in the navigation of ships. Collimation systems based on zone plates[45] have an accuracy of ±0.1 mm at a distance of 336 m. In the installation of large machines, a high precision of spatial alignment is required. The standard[46] used to be ±0.1 mm of spot instability for a distance of 27 m, 0.05 mm respectively within 100 m and a minimum resolution[47] of 0.01 mm. Studies have shown that thermal deformation of the invert telescope system had a large effect on the angular drift of the light beam. After reducing the heat transmission from the laser tube to the telescope, ±0.1" [seconds of arc] of stable accuracy can sometimes be obtained. After investigating the stability and beam propagation of point sources in a three point method, a 21 m long laser collimator with an accuracy of ±0.6-0.8 micron was developed. This system was capable of measuring the tidal variation of a manmade fault and can be used in earthquake forecast and in the measurement of dam deformation.[49]

Laser high voltage ammeter, based on the Faraday magneto-optic effect, is used in the noncontact measurement of super high voltage circuits. Field tests conducted at 100 A on 220,000 V line voltage showed an accuracy better than 3 percent.[50] An He-Ne laser may also be used as a light source in the noncontact high voltage measurement. Experiments conducted at 150,000 V using the electro-optic $LiNbO_3$ crystal as a Kerr cell and using transverse modulation showed a maximum relative error of 7.8 percent and an average relative error of 2 percent or less.[51]

In a laser micro-region spectrum analyzer, the laser beam is focused into an extremely fine light beam using a microscope, this beam is then used to vaporize the material to be tested, auxiliary electrodes are used to stimulate the emission of the spectrum and a spectrophotometer is then used in qualitative and quantitative analysis. The advantages are the high speed, accuracy and sensitivity of the analysis, no samples may be prepared. The technique is almost nondestructive, and has found wide applications. The relative sensitivity is 0.01 ~0.001 percent and the absolute sensitivity[52,53] is $10^{-9} \sim 10^{-13}$.

In addition, lasers have been used in unscaled laser topographer, laser theodolite, laser topographic mapper, laser conductivity meter, laser surface controller, laser labeller, laser printer, laser large screen television, laser gas detector, and so on.

IV. Laser Applications in Scientific Fields

As a new discipline and a new technology, lasers have quickly proliferated into other fields and made a major impact.

1. Laser applications in physics

Since the invention of the laser, it has brought profound influences in physics. Ever since the discovery of the second harmonic oscillation in 1961, nonlinear optics has always been an active field. The first issue of this journal had reported frequency doubled Nd:YAG-$LiIO_3$ lasers.[54] In 1977, harmonic output near the degenerate point was observed by pumping the $LiIO_3$ crystal in a double resonance cavity by the second harmonic of a Nd:YAG laser.[55] In 1978, degenerate four-wave mixing was first observed in a medium of an organic dye.[56] Extensive research followed on such nonlinear optics effects as multiphoton absorption, self-focusing, stimulated Raman scattering and phase conjugation. In recent years in-depth studies have been made on multiphoton ionization, nonlinear spectroscopy, optical bistable states, and transient coherence. Nonlinear optics in plasma, closely related to laser fusion, is becoming an active topic.[57] Four years ago China reported the theoretical investigation of stimulated scattering and harmonics in homogeneous and inhonogeneous plasmas. Nonlinear optics in fiber optic has also attracted attention, tenth order Stokes stimulated scattering at 546-702 nm has been observed in multimode quartz fiber optic pumped by frequency-doubled YAG:Nd laser.

The applications of high quality tunable lasers have stimulated the development of spectroscopy and formed a new branch of physics--laser spectroscopy. In recent years China has made considerable achievements not only in nonlinear laser spectroscopy but also in high resolution spectroscopy, photocurrent spectroscopy, Rydberg spectroscopy and microscopic sample high resolution spectroscopy. The hyperfine structure of ^{127}I was studied using the saturated absorption of 633 nm laser.[59] All the hyperfine structure components associated with the B $\leftarrow$ X electron transition 11-5R(127) band and 6-3 band P(33) were observed for the iodine molecule. The hyperfine structure and isotope shift[60] of the $2^2P \leftarrow 2^2S$ transition of a lithium atom were also observed. In addition, the problem of sub-natural linewidth two-photon spectroscopy was also investigated.[61]

China began the experimental and theoretical investigation of laser fusion in as early as 1965. China built two 10,000 MW Nd glass laser systems in 1973 and obtained about 1000 neutrons per pulse in deuterium and lithium deuteride targets. In 1974, a 200,000 MW single beam laser system was built, the last stage used a large aperture plate-like amplifier and the pulse width was 2 ns. Planar targets of deuterated polyethylene irradiated in this system produced a

neutron yield per pulse of 20,000. In 1977, glass shell targets were irradiated in a 6 beam 200,000 MW 1 ns laser system and the initial compression of the laser driven target material was observed.

2. Laser chemistry

In the past single photon processes were the main topics of study in conventional chemical spectroscopy and photochemistry. The development of laser has opened up a new area of chemistry associated with multiphoton processes. Single photon and double photon dissociation of $HgBr_2$ were studied with 192 nm excimer laser.[62] The multiphoton dissociation of CF_3CHCl_2 using a double frequency CO_2 laser separated the infrared multiphoton dissociation of deuterated methanol.[64] Coherent anti-Stokes Raman scattering was applied to the study of chemical spectroscopy.[65]

In the area of laser-induced chemical reaction, there have also been rapid progresses in recent years. For example, the reaction of halogenated ethane[66] was induced by an infrared laser pulse, and the dissociation and generation of carbonyl chloride in BCl_3 was induced by a CO_2 laser pulse.[67] Also studied were the laser-induced CF_2Cl_2 + NO reaction and reaction of platinum, gold and molybdenum on a silicon surface.

3. Isotope separation

Isotope separation by laser is based on the isotope shift effect of molecules and atoms. The laser radiation selectively excites some isotope particle and causes chemical or physical changes so that they may be separated. In the last 10 years, numerous reports have been published on the isotope separation of S, B, Li, U, and D in China.

4. Biomedical applications

China has been engaged in agricultural breeding research using laser for more than 10 years. It has not only helped to combat disease and produce higher yields but also resulted in a number of elite seeds in rice, wheat and cotton. Laser has also become a power tool of the veterinarians in treating some diseases in cattle, horse, hog, dog and chicken.

Lasers have found numerous medical applications. They not only serve as medical tools but also are used diagnostically and therapeutically.

Lasers have attracted wide attention in their role in diagnose and treating cancer. They are used as a surgical tool in removing tumors as well as in treating tumors. The photochemical reaction of laser irradiation changes the biological process of cancer. Lasers are used to block the supply of blood to the tumor and to kill the cancerous cells by heating. Laser irradiation may also stimulate immunity. In particular, China has been investigating the new laser-hemoporphyrin treatment since 1980.

The 10-year publication of the CHINESE JOURNAL OF LASERS (formerly LASERS) reflects the development of lasers in China. As we celebrate the 10th

anniversary of the JOURNAL, we review the development of laser applications in China and its contribution to the four modernizations of the nation. The JOURNAL has played an active role in promoting the application of laser technology in China.

The brief review presented here is based on some of the results published in the CHINESE JOURNAL OF LASERS (LASERS) and may not be a complete picture of laser development in China. Even so, it is clear that laser technology has a profound effect on a number of disciplines and fields and a great impact on the national economy. It will undoubtedly be one of the major areas of the new industrial revolution.

We wish the CHINESE JOURNAL OF LASERS a bright future as the laser industry prospers.

REFERENCES

1. Proceedings of the Technological Exchange Conference on the Industrial Applications of Laser in China, October 1983, Xian, p 17, published by the Chinese Optical Society Committee on Lasers.

2. Ibid, p 16.

3. Fu Chongda [1381 1504 1129] et al., Chin. J. Lasers, 10(20), 1(1983).

4. Shanghai Radio Plant No 13, Lasers, 1(1), 51(1974).

5. Shanghai Institute of Optics and Fine Mechanics, CO_2 laser group, Lasers 2(4), 10(1975).

6. Ibid, p 14.

7. Changchun Automobile Plant No 1, Sedan Plant, Lasers, 4(5), 10(1977).

8. Ibid, pp 12,13.

9. Pu Wanlin [5543 8001 2651], et al., Chin. J. Lasers, 10(11), 759(1983).

10. Jie Bomin [6043 0130 3046], et al., Chin. J. Lasers, 10(11), 759(1983).

11. Ibid, pp 9-11.

12. Xie Xiangsen [6200 4161 2773], et al., Chin. J. Lasers, 8(10), 30(1981).

13. Xie Xiangsen, et al., Chin. J. Lasers, 9(11), 734(1982).

14. Tan Yushan [6223 3768 1472], Chin. J. Lasers, 10(8-9), 641(1983).

15. Fujian Normal University, Physics Department, Holography Group, Lasers, 3(4), 20(1976).

16. Dong Bizhen [5516 4310 3791], et al., Lasers, 5(5-6), 35 (1978).

17. Xian Institute of Optics and Fine Mechanics, Chinese Academy of Sciences, Laboratory No 2, Holography Group, Lasers, 5(5-6), 36(1978).

18. Chen Yansong [7115 1484 2646], et al., Lasers, 5(5-6), 37(1978).

19. Qu Zhimin [2572 1807 2404], et al., Lasers 9(1), 17(1982).

20. Shi Zhiguo [2457 1807 2654], et al., Lasers, 8(6), 42(1981).

21. Jiang Jinhu [1203 6920 5706], et al., Chin. J. Lasers, 10(1), 49(1983).

22. Huang Letian [7806 2867 1131], et al., Lasers, 6(7), 54(1979).

23. Zhao Yeying [6392 8518 5391], et al., Lasers, 7(4), 32(1980).

24. Lasers, 5(4), 61(1978).

25. Shi Daojun [4258 6670 6874], et al., Chin. J. Lasers, 10(7), 439(1983).

26. Jiang Yaguang [1203 0068 0342], et al., Chin. J. Lasers, 10(8-9), 654(1983).

27. Zheng Shihai [6774 1597 3189], et al., Lasers, 7(2), 55(1980).

28. Feng Yufen [7456 3768 5358], Chin. J. Lasers, 11(3), 131(1984).

29. Mo Guoguang [3019 0948 0342], et al., Chin. J. Lasers, 10(8-9), 647(1983).

30. Zhuang Songlin [8369 2646 2651], et al., Chin. J. Lasers, 10(8-9), 649(1983).

31. Yuan Weiben [5913 4850 2609], Lasers, 8(1), 39(1981).

32. Ma Deyan [7456 1795 1484], Lasers, 9(11), 727(1982).

33. Zhou Zhengwen [0719 2973 2429], Lasers, 8(11), 46(1981).

34. The People's Liberation Army No 706 unit, Lasers, 2(4), 7(1975).

35. Ningxia Hui Autonomous Region, Yinhe Meter Plant, Lasers, 3(5), 13(1976).

36. Changchun Institute of Optics and Fine Mechanics, Chinese Academy of Sciences, Laser Velocimeter Group, Lasers, 4(4), 10(1977).

37. Shen Xiong [3088 3574], et al., 9(10), 645(1982).

38. Deng Ximing [6772 6932 6900], et al., Chin. J. Lasers, 10(12), 843(1983).

39. Li Depei [2621 1795 1014], et al., Lasers, 1(2), 6(1974).

40. Beijing Scientific Instrument Plant, Lasers, 3(2), 19(1976).

41. Liang Xiangchun [2733 0686 2504], et al., Lasers, 6(4), 47(1979).

42. Liang Xiangchun, et al., Lasers, 7(7), 41(1980).

43. Luo Yizu [5012 2034 4371], et al., Chin. J. Lasers, 10(4), 225(1983).

44. Chen Yuming [7115 6877 2494], et al., Lasers, 7(10), 38(1980).

45. Wuhan Survey College, Lasers, 3(4), 11(1976).

46. Nanjing Aviation College, Laser Automation Group, Lasers, 1(2), 44(1974).

47. Wu Cunkai [0702 1317 1956], et al., Lasers, 2(2), 55(1975).

48. Wang Shaomin [3769 4801 3146] et al., Lasers, 5(1), 12(1978).

49. Wang Shaomin, et al., 7(3), 54(1980).

50. Li Dongjian [2621 2639 0256], Lasers, 6(11), 60(1979).

51. Zhao Kun [6392 3824], et al., Lasers, 7(7), 51(1980).

52. Jilin Joint Research Group, Lasers, 3(1), 20(1976).

53. Xinjiang Uygur Autonomous Region, Geological Administration Laboratory, Laser Group, Lasers, 3(2), 8(1976).

54. Shanghai Jiaotung Research Group, Laser Laboratory, Device Group, Lasers, 1(1), 10(1974).

55. Chu Guiyin [0443 2710 5593] et al., Lasers, 5(5-6), 31(1978).

56. Wu Cunkai, Lasers, 6(3), 12(1979).

57. Tan Weihan [6223 4850 5060], et al., Lasers, 7(5-6), 18(1980).

58. Gao Peijuan [7559 0160 1227], et al., Lasers, 7(4), 11(1980).

59. Li Fu [2621 2494 0342], et al., Lasers 10(2), 85(1983).

60. Li Mingguang [2621 2494 0342], et al., Lasers, 9(7), 434(1982).

61. Huang Yongkai [7806 3057 2818], Chin. J. Lasers, 10(4), 193(1983).

62. Yuan Cailai [5913 2088 0171], Lasers, 8(4), 62(1981).

63. Pan Daren [3382 1129 0117], Lasers, 9(3), 152(1982).

64. Zhang Yunwu [1728 0336 2976], et al., Lasers, 8(1), 56(1981).

65. Guo Zhen [7559 2182], et al., Chin. J. Lasers, 10(1), 13(1983).

66. Wang Wenyun [3769 2429 7301], et al., Lasers, 9(10), 651(1982).

67. Li Li [2621 7787], et al., Lasers, 9(9), 570(1982).

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APPLIED SCIENCES

ANALYSIS OF FIBER-GYROSCOPES DISCUSSED

Shanghai ZHONGGUO JIGUANG [CHINESE JOURNAL OF LASERS] in Chinese No 10, 20 Oct 84 pp 598-601

[Article by Sun Li [1327 7812] and Deng Feifan [6772 7378 1581]: "Function Analysis and Parameters Determination of Resonator Type Fiber-Gyroscopes"]

[Text] Abstract

An analytical formula for calculating the optimum length of resonator type fiber-gyroscopes has been deduced. Taking into account stimulated Brillouin scattering, the sensitivity limit of fiber-gyroscopes, the determination of the coupling coefficient and the requirements of splice loss are discussed.

I. Introduction

The research of optical gyroscope is progressing from sourced gyroscope to source less gyroscope, the latter is generally achieved using fiber optic. Fiber-gyroscopes can be divided into two types, the interference type and the resonance type. In the interference gyroscope, loops of fiber optic form a Sagnac interferometer and the rotation speed with respect to an inertia space is obtained by measuring the movement of the interference fringes. The interferometer gyroscope has been studied extensively in recent years.[1-3] In the resonator gyroscope, loops of fiber optic form a closed resonance cavity (see Fig. 1), the laser light enters the cavity through the coupler C_1 in both directions. The forward and reversed vibrations exit through another coupler C_2 and are detected by photoelectric devices[4] a_1 and a_2.

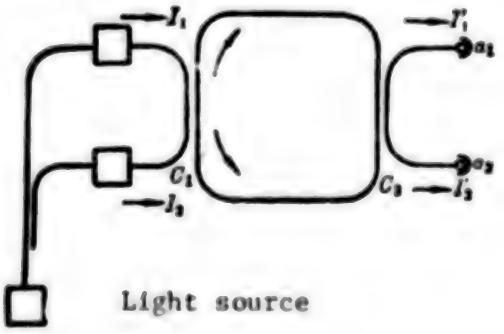

Fig. 1

From the Sagnac effect, it can be shown[9] that the frequency difference Δf of the forward and reverse directions is given by

$$\Delta f = \frac{4A}{\lambda \langle p \rangle} \Omega \qquad (1)$$

where A is the area of one loop of fiber, $\langle p \rangle$ is the optical path length corresponding to the circumference of the loop, λ is the wavelength in vacuum and Ω is the angular velocity relative to the inertia system. The usual practice is to track the resonance frequency with the incoming light frequency and compute Ω from Eq.(1) using the measured frequency difference. This type of gyroscope has not been fully developed.

D. Shupe[4], in his article of 1981, analyzed the resonator gyroscope and claimed that its accuracy is comparable to that of the interferometer fiber-gyroscope. Since the accuracy of the resonator fiber-gyroscope does not depend on the number of turns of the optical fiber, as indicated in Eq.(1), a shorter length or even one turn of fiber can be used (provided that splice and coupling losses are small) and thereby greatly reduce the temperature induced drift. In this article we analyzed the resonator fiber-gyroscope and found that the fiber length for the highest sensitivity should not be one turn. We also determined the coupling coefficient needed in the design and the achievable accuracy in measuring the angular velocity.

II. Optimum Length of Fiber Optics

For simplicity, we consider the case of a symmetric resonance cavity with identical C_1 and C_2. The coupling coefficient is C, the transmission coefficient is T and, when losses are omitted, T + C = 1. The two sections of fiber optic between C_1 and C_2 are identical, the loss coefficient is α_T and the splice loss and the coupling loss lumped together is represented by α_{sc} and is distributed along the two sections of fiber optic. Using the Fabry-Pérot method, the transmissivity of the resonator is given by[10]:

$$\frac{P_o}{P_i} = \frac{G}{1 + F \sin^2 \delta/2} \qquad (2)$$

where P_i is the input light power into the coupler C_1 (I_1 in Fig. 1) and P_o is the output power out of the coupler C_2 (I_2 in Fig. 1). δ is the phase difference associated with the entire fiber optic loop optic path $\langle L \rangle$. If we write the qth resonance frequency as ν_q, the incident laser frequency as ν and the speed of light in vacuum as c_o, then,

$$\delta = \frac{2\pi \langle L \rangle}{c_o} (\nu - \nu_q) \qquad (3)$$

In Eq.(2), G is the maximum transmissivity and is given by

$$G=\frac{C^2\exp(-\alpha)}{[1-T^2\exp(-\alpha)]^2} \qquad (4)$$

F is known as the finess and is equal to

$$F=\frac{4T\exp(-\alpha)}{[1-T^2\exp(-\alpha)]^2} \qquad (5)$$

In Eqs. (4) and (5), α is one-half the total loss, that is,

$$\alpha=\frac{1}{2}(\alpha_T L+\alpha_{sc}) \qquad (6)$$

Based on Eq. (2), we can produce a series of curves relating the transmissivity to the incident laser frequency ν, as shown in Fig. 2. Obviously, the larger, the F, the sharper the transmission peaks. Fiber-gyroscopes operate under the condition of sharp peaks, only then, the frequency tracking can be precise. The actual value of F is always much greater than unity. The discussion below is based on this assumption.

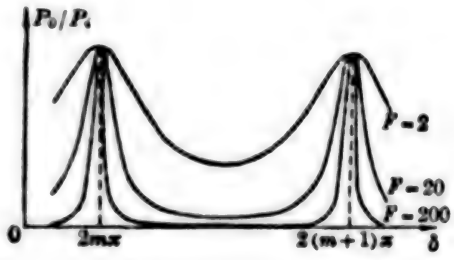

Fig. 2

There are a number of frequency tracking methods, all based on the principle of feedback. The signal due to the relative shift of the light frequency and the cavity frequency is detected with a modulation technique and fed back to make the two frequencies coincide. In order to have the best modulation result, the modulation signal should naturally be at the maximum slope of the transmission peak. Calculation shows that the transmissivity at the maximum slope is equal to

$$\frac{P_0}{P_i}=\frac{2}{3}G \qquad (7)$$

and the Maximum value of the slope, K_{max}, is equal to

$$K_{max}=\frac{4\sqrt{2}\,\pi\langle L\rangle}{9c_0}G\sqrt{F}$$

where c_o is the speed of light in vacuum. The shot noise current i_n is related to the average detected current $\bar{I}$ by the following relationship[11]

$$i_n = \sqrt{2eB\bar{I}}$$

where e is the electron charge and B is the bandwidth of the detection circuit. The relationship between the current and the optical power is

$$i = \frac{e\eta}{h\nu} P$$

where η is the quantum efficiency of the detector and h is Planck's constant. The corresponding noise power is

$$P_n = \sqrt{\frac{4Bh\nu G}{3\eta}} P_t,$$

and the frequency difference $\delta\nu$ corresponding to this noise power should be

$$\delta\nu = \frac{P_n/P_t}{K_{max}}$$

Since the frequency difference of the light in the forward and reversed directions add according to the law of error and should be multiplied by $\sqrt{2}$, the sensitivity of the angular velocity is

$$\delta\Omega = \frac{9c_o\lambda\langle p\rangle}{16\pi A}\sqrt{\frac{4Bh\nu}{3\eta P_t}}\frac{1}{\langle L\rangle\sqrt{GF}} \qquad (8)$$

To obtain the optimum length of the fiber optic, we find the extremum value of L from Eq. (8). Using the exponential expansion approximation and recall that F>>1, we finally obtain an analytical expression for the optimum length:

$$L_{opt} = \frac{2C+\alpha_{sc}}{\alpha_T} \qquad (9)$$

At the optimum length, the minimum measurable angular velocity is

$$\delta\Omega_{min} = M\frac{2C+\alpha_{sc}}{2C}\alpha_T \qquad (10)$$

where M is a collection of constants:

$$M = \frac{9c_o\lambda\langle p\rangle}{16\pi A}\left[\frac{4Bh\nu}{3\eta P_t}\right]^{1/2}$$

Using computer curve tracing, D. Shupe found that, for fixed α_T and α_{sc}, the value of C corresponding to an optimum length of 1600 m is 0.3. Using our Eq. (9), substituting the numerical values used by D. Shupe, α_T = 2 dB/km,

α_{sc} = 0.7 dB, C = 0.3 = 1.3 dB and F ≈ 5, we obtained an optimum length of 1650 m. The agreement is very good. Equation (9) is especially useful in that it explicitly shows the effects of the various parameters on the optimum length.

III. Parameter Selection

Equation (9) shows that, to minimize the length of the fiber, the coupling coefficient C and the attenuation should be as small as possible. Although a larger α_T may also reduce L_{opt}, but it also increases $\delta\Omega_{min}$ (see Eq.(10)) and is therefore undesirable.

We now consider the effects of C and α_{sc} and examine if they are the smaller the better. C is the coupling coefficient of the cavity with the exterior; the smaller the C, the greater the power ratio between the interior and the exterior of the cavity. For a constant output power, the oscillation in the cavity is stronger for a smaller C. From the definition of C, the cavity power P_c is related to the output power P_o:

$$P_c = \frac{1}{C} P_o$$

Under optimal conditions, P_o is roughly equal to one half of the i put power P_i and the other half is dissipated in the cavity, that is,

$$P_c \approx \frac{1}{2C} P_i$$

This means that for a given input power, P_c is greater if C is small. Since the diameter of the fiber is very small, the field intensity in the fiber becomes very large as P_c increases. Analysis[5] shows that stimulated Brillouin scattering first appears in the fiber as the field intensity increases. Once the stimulated scattering takes place, the attenuation of the fiber optic increases rapidly and becomes unstable. Therefore, the threshold for stimulated Brillouin scattering limits P_c and C. In general[5,6], it is reasonable to assume P_c < 10 mW. For P_i = 1 mW, C is of the order of 0.05 and values smaller than that are not allowed. It is obviously not desirable to increase C by lowering P_i because it has a direct degrading effect on the signal to noise ratio of the detector.

Once the value of C is approximately determined, the value of α_{sc} is also decided. Because 2C and α_{sc} are additive in Eqs. (9) and (10), further reduction of α_{sc} is meaningless if α_{sc} is significantly less than 2C. Therefore, it is adequate to keep α_{sc} below 0.02.

Based on the values of C and α_{sc} and the attenuation of current available fiber optic, $\alpha_T \approx 1$ dB/km ≈ 0.05/km, the optimum length of the fiber optic can be computed:

$$L_{opt} = \frac{2C + \alpha_{sc}}{\alpha_T} = 200 \sim 400 \quad \text{m}$$

The two numbers above (200 m and 400 m) correspond respectively to $\alpha_{sc} << 2C$ and $\alpha_{sc} \approx 2C$. Hence, with stimulated scattering taken into account, the optimum length is at least 200 m and not 0.5 m (one loop) no matter how low the coupling loss and splice loss are. Shupe and other researchers did not realize that when the fiber optic is very short and the loss is very low, the power inside the cavity is strong enough to cause stimulated Brillouin scattering and they reached the evidently incorrect conclusion that the length of the fiber optic can be shortened indefinitely.

Under the optimum conditions stated above, we may calculate the shot noise limited sensitivity. For P_i = 1 mW, we have

$$\frac{\delta\Omega_{min}}{\sqrt{B}} \approx \frac{1}{6C} \times 10^{-3} \quad \text{deg}/\sqrt{\text{hr}}$$

If the sampling time is fixed at 1 minute, the corresponding bandwidth may be taken as B = 1/60 Hz and

$$\delta\Omega_{min} = 1.2 \times 10^{-4} \text{ deg/hr}$$

This value is much lower than the estimate by Liang et al.[7] incidentally, their bandwidth of B ~ 1 Hz in estimating such high precision angular velocity is inappropriate because the frequency difference in such cases is much less than 1 Hz and the sampling time must be sufficiently long for such small frequency difference.

Under these optimum conditions the width of the transmission curve is $\Gamma \approx 1.6 \times 10^4$ Hz. This value sets a limit for the bandwidth of the incident light--it should be considerably less than this value so that the sensitivity obtained in the analysis above is not degraded.

IV. Remaining Problems

Based on the analysis above, resonance type fiber-gyroscopes can meet the accuracy requirements of the application, the key problem is the coupling loss and the splice loss, which amount to about 0.4 dB. If these losses can be reduced to 0.1 dB, then the corresponding α_{sc} = 0.23x0.1 = 0.023 and the design requirements will be met. Stable coupler with a small coupling coefficient (C = 0.05) still requires more effort. In addition, there exist the following remaining problems.

First, there is the polarization problem. In single mode fiber optics there exit two mutually orthogonal polarizations. Due to unavoidable birefringence, the wave velocities of these two polarizations are slightly different, which lead to different resonance frequencies. Moreover, birefringence changes with the environmental conditions in a random fashion and results in inaccuracies in frequency tracking and intolerable error. Therefore, one must use single mode single polarization fiber optic.

The serious problem is the zero drift cause by unequal intensity of the forward and reversed light. As pointed out by S. Ezekiel et al[8], the intensity difference between the forward direction and the reversed direction is 1 μW and the drift due to nonlinear optical effect can be as high as 0.1 deg/hr for a fiber length of 100 m. The optical power in the fiber cavity is of the order of 10 mW and it is difficult to maintain the difference within 1 μW. This may be a crucial weakness of the resonator type fiber-gyroscope. (The intensity in interferometer type fiber-gyroscopes is often below 0.1 mW.) There are many reasons for the intensity difference such as the instability of the couplers and the asymmetry in the attenuation. Drastic measures must be taken, sometimes even sacrificing the optimum conditions, in order to reduce the fiber length and the effects of the intensity difference.

REFERENCES

1. V. Vali, R. W. Shorthill; Appl. Opt. 1976, 15, 1099.
2. R. A. Bergh et al., Optical Society of America 1981, 6, 502.
3. J. L. Davis, S. Ezekiel, Opt. Lett. 1981, 6, 505.
4. D. M. Shupe, Appl. Opt. 1981, 20, 286.
5. Shih-Chun Lin et al., Appl. Opt. 1979, 18, 915.
6. A. Yariv, Quantum Electronics, John Wiley and Sons, Inc., 1975, p 497.
7. Jiang Yanan [1203 0068 0589], et al., Lasers, 8(9), 34(1981).
8. S. Ezekiel, et al., Opt. Lett., 1982, 7, No 9.
9. A. H. Rosenthal, JOSA, 1962, 52, 1143.
10. M. Born and E. Wolf, Optics, p. 429.
11. A. Yariv, Introduction to Optical Electronics, New York Holt, 1971, p 281.

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APPLIED SCIENCES

X-RAY LITHOGRAPHY AND VLSI CIRCUITS

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[Article by Gu Bichun [7357 2672 2504], Semiconductor Institute, Chinese Academy of Sciences: "X-ray Lithography and VLSI Circuits"]

[Text] At present, most of the research work in integrated circuits is focused in the development of VLSI circuits. If current trends continue, the geometry processing technology using lines 1 to 0.5 μm wide (also called submicrofabrication) will be standard in the design of VLSI between 1985 and 1990. The shrinkage of the feature sizes will greatly reduce the production costs of IC, e.g., storage units with linewidth of 2 μm cost 3,200 microcents (US cents) to make, those with linewidth of 1,925 microcents and the ones using lines 0.5 μm wide cost no more than 84 microcents to produce. Because of the obvious economical gains it brings, there have been rapid advances in the technologies that the manufacturing of VLSI circuits calls for, especially in the field of optical lithographies, where major technological breakthroughs have been made.

I. The Basic Requirements of VLSI Production on Optical Lithographies

1. Lines of High Resolutions

The minimum feature requirement of a VLSI device made up of 300,000 gates is a linewidth of 1 to 1.5 μm; the linewidth of a ULSI (ultra large-scale integrated) device of 1 million gates should be no more than 0.5

2. Registration Techniques With High Accuracies

The circuit structures of VLSI will conceivably be more complicated than that of ordinary integrated circuits. For various functioning circuits, the patterns differ, i.e., chips have to go through as many printing steps as needed, usually five to eight times; thus raises the registration problem between the multiple lithographic levels during fabrication. For example, the minimum accuracy is $\pm$ 0.15 μm for lines 0.5 μm wide. Registrations with lower accuracies than this mean less geometries can be printed on a chip, making circuit designing more difficult.

3. Throughput and Yields

Today, silicone chips of ϕ125 mm have already found their way in the IC fabrication. It is obvious that processing chips of larger diameters such as this is much more economically viable than processing chips of smaller sizes, since silicone chips with larger diameters afford larger areas for exposure during optical printing, thus requires less processing time, i.e., higher efficiency and consequently lower costs. However, this argument is based on the assumption that the procedures employed are high yielding ones, for example, in the process to print circuits of geometries of 1x10 μm^2 on chips of ϕ100 mm, there cannot be more than 1 defect per cm^2 out of the thousands of patterns printed. In order to assure high yieldings in the VLSI fabrication, it is imperative to keep the defect density (defects per cm^2) low in the photolithography.

Scientists started to study the feasibility of utilizing energy sources of lower wavelengths to improve resolutions in optical lithography in the late 1950's and early 1960's and because of the diffraction problem of UV-light (wavelength 4000A) at required wavelengths for printing prescribed linewidths, the electron beam lithography, which uses sources of wavelengths of less than 1A, was developed and this procedure, albeit generates fine lines of high resolutions, its yields in design imaging are rather poor. Spear and Smith[1], both of Massachusetts Institute of Technology, proposed the use of X-ray as the energy for lithography in 1972. Later through more than a decade's study by scientists, X-ray lithography has been developed into a full fledged lithographic process; Bell Telephone Laboratory has adopted this X-ray technique in its intermediate production line for the fabrication of a metal oxide semiconductor device with channels of 0.3 μm wide[2]. At present, the development of X-ray lithography are being conducted in the United States, Japan, West Germany, France and the United Kingdom. Papers published by scientists from the aforementioned countries show that the X-ray approach produces the one kind of technology that meets the demands of fabrication of complex VLSI devices.

II. Advantages of X-Ray Lithography

The X-ray lithography has attracted great interests of major laboratories all over the world because it offers the following technical advantages:

1. The Attainable Resolution of X-Ray Lithography Can Be as High as 50 A. The patterns of linewidth 150 A, replicated by the X-ray process as shown in figure 1, have a variation of only $\pm$50A. The mask used in this printing was made by a technique called shadowing.

2. The X-Ray Lithography Produces High-Quality Printings

(1) Fabricating VLSI devices requires pattern replication processes that are able to image patterns of high gate length to linewidth ratios (i.e. length/linewidth ratios) on the polymer film, the larger the ratio, the better the printing. As shown in figure 2, a pattern, printed by the X-ray process, features a linewidth of 0.2 μm and gate length of 2 μm giving a length/linewidth ratio of 10. Most other optical imaging methods cannot reproduce topographies as sharply defined as this.

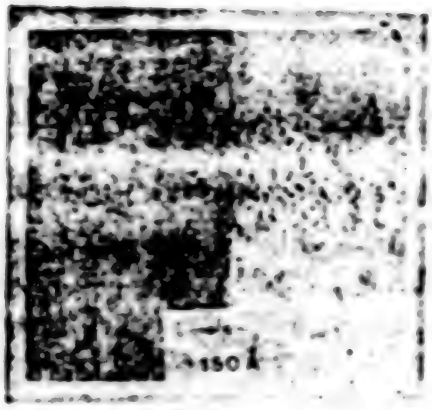


Figure 1. The 150 A wide, high resolution lines produced by X-ray lithography on a polymethyl methacrylate (PMMA) film.

Figure 2. The pattern made by X-ray lithography on a PMMA film features a length/width ratio of 10.

Why does VLSI pattern replication require polymer film imaging with high length/width ratios?

Figure 3 provides an answer to this question; when the light beam penetrates the wafer on the substrate, the polymer film, on top of the wafer should be thick enough to print the feature patterns where other etching techniques failed to do. Also, note the differences between figures 2 and 3, the polymer film presents a high and steep profile; when the lift-off process is used to make the aluminum feature patterns, metallic aluminum is deposited on the substrate surface either by sputtering or evaporation method to keep the thickness of polymer film greater than that of aluminum, the polymer film can, then, be removed with solvents and leaves the aluminum geometries behind; even in the etching process, the capability to print with high length/width serve to guarantee the faithful replication of design patterns.

(2) Because of its characteristic penetrating power, the X-ray lithography also diminishes dust interferences during the fabrication processes, where a small dust particle on the polymer film or mask is enough to cause a defect on the printed pattern in other optical printing procedures, which are usually

carried in ultra-clean environments with a cleanness rating of 100 (the rating 100 indicates that the dust particles with diameters equal or larger than 0.5 μm are less than 3.5/L). These small particles usually come from elements of low atomic numbers, such as carbon, silicone, oxygen, etc., X-rays can easily penetrate particles of this nature with diameters around 0.5 μm, especially when using X-rays of short wavelengths and large deflection angles on the polymer film, the interferences of dust particles are negligible (see figure 4).

Figure 3. After X-ray exposure, the patterns on the substrate made by light beam from the polymer film.

Figure 4. The characteristic penetrating power of X-ray

Key:

a. A 10 μm- wax line made on the mask
b. By making use of the penetrating power of the X-ray, the wax line merely leaves a mark on the polymer film and there is no detectable defect; in practice, the mark can be completely eliminated

By the definition of cleanness ratings given in the previous paragraph, it is obvious that ultra-clean rooms with a cleanness rating 100 are no longer suited

for the manufacturing of storage units of 256K bits with lines 1 to 1.5 μm wide (there are more than 300,000 gates per chip) because the production of VLSI devices with linewidths of such small magnitude should be conducted in environments in which no particles of diameters larger than 0.3 μm are present; this means a cleanness rating of 10,000. To achieve this degree of dust-free requirement, not only poses technical problems but also demands large capital costs. The insensitivity of X-rays to dust helps to improve the qualities of the products as well as alleviate the strict no-dust requirements in the fabrication of VLSI devices."

A further benefit of the X-ray optical printing is its ability to penetrate some of the defects on the mask, an ability equivalent in effect in decreasing the defect density in the VLSI lithography, thus, the use of X-rays helps to improve the mask processing techniques and consequently, lower the production costs. This effect is illustrated in figures 5(a) and (b); figure 5(a) shows the pattern of the X-ray mask, to the right, the group of lines are connected by a thin layer of gold which fills the 0.5 μm gap between lines; figure 5(b) gives the pattern printed by X-rey lithography, the 0.5 μm gaps are clearly discernable, as a result of the restoring effect of the X-ray, an act impossible to be repeated by other printing processes.

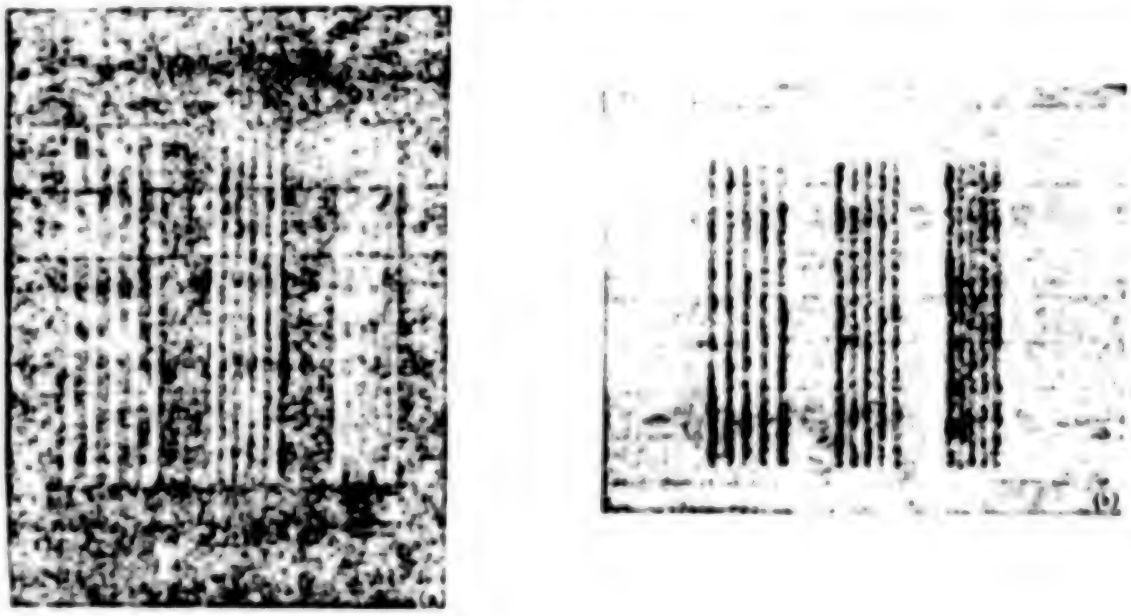


Figure 5. The mending of mask defects by the characteristic penetrating power of X-rays

(a) The gold resolution lines on the X-ray mask, all the lines are 0.75 μm wide; the gap between lines in the left hand side is 0.75 μm; a thin gold film filled the gap of 0.5 μm between lines in the right hand side

(b) The pattern imaged after the polymer film was exposed to the X-ray showed there was no polymer film left in the gap between the lines of linewidth 0.75 μm in the right hand side, a proof of the mending effect of X-rays

3. X-Ray Masks Have Longer Lifetime, Comparable to That of Projection Process Masks

The masks used in photoprinting processes of VLSI are expensive to make, therefore, how to keep them from being damaged is an important problem to solve in the development of optical lithographies. The projection printing process had been developed to replace the conventional contact printing process largely because of damaging of masks in the printing steps. Table 1 compares the smallest attainable linewidths and distances between silicone chips and masks of the 3 modes of proximity printing using different energy sources. The X-ray masks can be used for several thousands exposures[5] where UV and far UV proximity printing masks can only be used for around a hundred or less exposures.

Table 1. Comparisons of the smallest attainable linewidths and distances between silicone chips and masks of three modes of proximity printing processes using different light sources

Parameters	UV Light	Far UV Light	X-Ray
distance of chip-mask (μm)	15	20	40
the smallest attainable linewidth (μm)	3	2	0.3

When synchrotron radiation is used as the light source of X-ray lithography, since the synchronized radiation is well collimated, the distance between the X-ray mask and the silicone chip can be as high as 1 mm, as shown in figure 6.

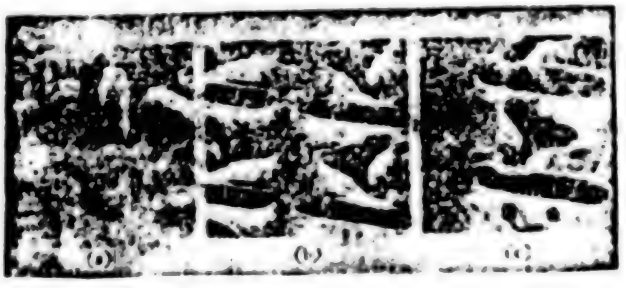


Figure 6. Patterns printed by X-ray lithography with synchrotron radiation as the light source using a polymethyl methacrylate (PMMA) film.

The lines on the mask are 1 μm wide. The exposure time was 3 minutes. The distance between the mask and the chip was (a) 0.14 mm, (b) 0.54 mm and (c) 1.04 mm respectively.

III. Comparisons of X-Ray Lithography and Other Photoprinting Processes

We cannot make an impartial assessment of a technical process if we look at it solely from the point of view of technical advantages, economical considerations should also be included in the evaluation, in other words, the most

cost-effective process for lithography among the many contenders in the field of VLSI fabrication should be the one which offers the most advanced technology, requires the least capital-costs yet brings the largest profits.

1. Comparisons of Figures of Merit of Optical Printing Processes

The figure of merit of a process, an evaluation of cost-effectiveness or profitability, is determined by the emprical relationship:

$$\text{Figure of merit} = \frac{\text{thoroughput}}{(1+0.15\text{defects})^8 \times \text{cost} \times (\text{linewidth})^2}$$

The figures of merit calculated using the above formula are listed in table 2. The results of calculation using a different figure of merit formula are given in table 3.

Table 2. Comparison of Photomasking Techniques

	Typical line width (μm)	Equipment cost (x $ 10^3)	Achievable defect level (per cm^2)	Throughput (wafers/h)	Figure of merit (x 10^6)
Contact	3	30	2.5	50	14
Projection	2	185	1	65	29
Far-ultraviolet Projection	1	200	1	50	82
Step-and-repeat Projection	1	350	1	20	19
Electron beam	0.5	1,500	0.5	10	15
X-Ray	0.3	300	1	20	218

Table 3. Comparison of Optical S&R, Full Wafer X-Ray and Electron Beam Lithographic Technologies

	Optical S & R	Full Wafer X-Ray	Electron Beam
Useful Resolution (R), micrometers	1.0	0.25	0.1
Throughput (N), wafer levels per hour	40	75	10
Exposure system cost (C), dollars	700 K	225 K	3 M
Clean room area (A), ft^2 per system	50	12	65
Figure of Merit, $N/(C+10A)R^2$	33	3480	274

As shown in tables 2 and 3, the X-ray lithography gives the highest figure of merit in both tables, although the calculated figures in the two tables came from different sources and were obtained by different formulas using different parameters and indexes.

2. Costs Comparisons of Photoprinting Technologies

Table 4 shows that the costs of different optical processes in the pattern reprinting of VLSI vary. It clearly indicates that although the X-ray lithography using synchrotron radiation approach demands the heaviest system cost, but this mode of X-ray lithography is able to produce at the lowest cost per chip and not surprisingly, rapid advances have been made in the application of the synchrotron radiation as the power source for the X-ray imaging process. Furthermore, the cost per chip is lower than those of other X-ray processes using ordinary power sources; in addition, it is projected that the cost per chip of the synchrotron radiation system can be lowered another 50 percent if aiming at producing geometries with a 0.5 μm-resolution; an indication of the great potential of this process.

Table 4. Comparison of Cost Per Chip of Photoprinting Processes

(1)		(2)	(3)	(4)	(5)
(6)		2			0.5
(7)		1	1.0		2.00
(8)		1	1–4		1.00–32.00
(9)	(1) (10)	1	1		1.00
	(2) 步进重复 (11)	1	1		2.00
(12)	(13) 100 cm^2	1	0.10		0.25–0.5
	(14) 10 cm^2	1	0.16	same as above	0.40–0.80
	(15) 4 cm^2	1	0.40	same as above	1.25–2.50
	(16) 1 cm^2	1	1.00	same as above	2.50–5.00

Cost per chip = resolution x exposure time x system cost x $0.50 ÷ $100,000

* Polymer films with high sensitivities were used.

** High diffractive angles, dry etching process and polymer films with low sensitivities were used; system cost is the cost for X-ray lithography station only, not for the whole electron storaging ring.

Key:

(1) Photoprinting processes
(2) Useful resolution
(3) Exposure time (minutes)
(4) System cost, dollars
(5) Cost per chip, dollars
(6) Projection exposure
(7) Step-and-repeat S & R
(8) Electron beam
(9) Ordinary source powered X-ray
(10) Large area
(11) Step-and-repeat
(12) X-ray with synchrotron radiation
(13) Exposure area 100 cm^2
(14) Exposure area 10 cm^2
(15) Exposure area 4 cm^2
(16) Exposure area 1 cm^2

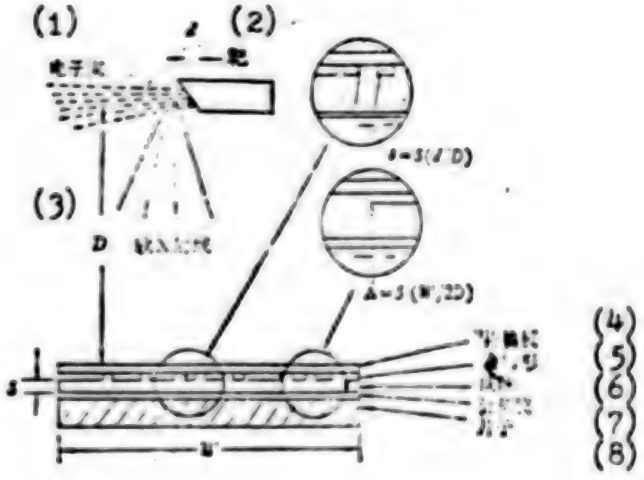
IV. The Principle of X-Ray Lithography

The X-ray process is analogous to conventional contact printing, however, there are some differences as given below:

(1) The wavelength used in X-ray lithographies falls in the range of 4.37-4.48 A; dimensions of VLSI geometries are much larger than the X-ray wavelengths, yet, smaller than the wavelengths (4000 A) used in the conventional processes, thus, the employment of X-rays as the source can effectively all the wavelength-related diffraction problems.

(2) X-rays travel in straight lines, do not involve the complicated calculations usually associated with the optical systems. Figure 7 shows a basic X-ray lithography diagram.

Figure 7. X-ray lithography.



Key:

(1) Electron Beam	(5) Absorber
(2) Target	(6) Spacer
(3) X-ray	(7) Polymer film
(4) Mask	(8) Wafer

The following relationship can be determined from the figure using simple trigonometry:

$\delta = S(d/D)$
$\Delta = S(W/2D)$

where δ is the minimum attainable resolution, Δ, the degree in geometric distortion, d, the source diameter, D, the source to wafer distance, S, the gap between the wafer and the mask and W is the distance from any point of the wafer to the perpendicular direction of the X-ray source to the wafer.

The 2 equations, giving the line resolution, δ and Δ, the penumbral distortion can be considered as the starting point to design the X-ray system. Since varies with S, the magnification of a mask pattern can be adjusted by altering S. Thus, homogeneous distortion, due to high temperature processings can be compensated for by changing the mask-to-wafer gap; a unique advantage of X-ray lithography comparing to other parallel exposure techniques.[8]

V. Application of X-Ray Lithography to the Fabrication of VLSI

1. The beginning of the application of X-ray lithography in the VLSI production signals the end of the usefulness of the step-and-repeat optical S & R printing; results with its pilot line processing indicates that X-ray lithography is best suited for this approach.[9]

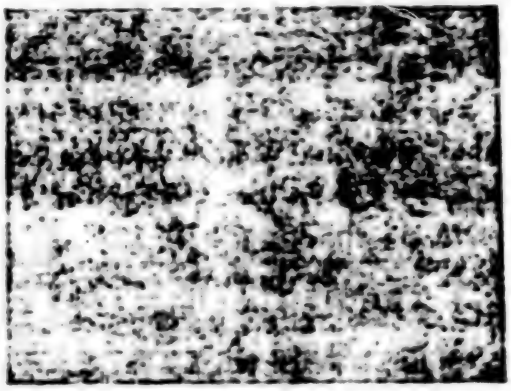
At present, the X-ray system which uses a source with wavelength of 405 μm and numerical aperture of 0.41 can attain a minimum linewidth of 0.8 μm is one of the more promising approaches; however, there are also disadvantages: the small exposure area of 6x6 cm^2 only and an image depth of $\pm$ 1.2 μm; in addition, special techniques are required in the treatment of the photoresist and maintaining reflux/influx ration. In general, the printing qualities are not very good. However, this approach is well-suited for making masks, since zero-defect, 5 or 10 times larger parent masks can be readily obtained by this method; the parent masks are good for printing smaller wafers with surface variations of $\pm$ 1 μm by reduction projection process. It is much more cost-effective and efficient to achieve the same purpose by this approach than by the electron beam process. Furthermore, this approach can best meet our requirements, its ability to produce X-ray masks at lower costs is a big plus, an approach makes the best use of the technical advantages of X-ray lithography. Conceivably, this approach can be very useful in manufacturing storage units of 256K bits.

Figure 8 shows the first X-ray lithography unit (1) made in China. A photoresist pattern of linewidth 1 μm and polymer film depth 2 μm is given in figure 9.[10]

Figure 8. The first X-ray lithography unit made in China.

(1) jointly developed Semiconductor Institute, Chinese Academy of Science, Shanghai Optical Instruments Factory, Wuxi Chemical Engineering Institute, Shanghai Automation Institute and Hangzhou Electron Tubes Factory.

Figure 9. The pattern imaged on the photoresist by X-ray lithography using the first X-ray lithographic unit designed and manufactured in China.



2. A combination of X-ray lithography and electron beam process is better suited for printing geometries with linewidths around 0.5 μm; a step-and-repeat printing strategy should be used if using the X-ray printing process only.

The electron beam optical printing process has been developed into a more advanced stage and used for transferring patterns with high resolutions, yet, some technical problems remained: its low throughput and inability to break through the barrier to replicating with high length/width ratios and causes technical difficulties in printing X-ray masks. These drawbacks can be made up by the concurrent use of X-ray lithography. For example, in the printing of geometries of 0.5 μm linewidth, the patterns can first be made by the electron beam process, the features so obtained can be developed on a gold substrate of 1000 A thick by the dry etching process to yield gold feature patterns of high qualities for X-ray masks. In optical printing with gold patterns as thick as 1000 A, X-rays of wavelengths longer than 10 A should be used (if X-ray of shorter wavelengths are used, its gold-penetrating ability can cause pattern deteriorations on polymer film). Synchrotron radiations are ideal for this kind of application, in terms of process-efficiency: its X-ray radiations have wavelengths longer than 10 A and an intensity 4 to 5 magnitudes stronger than that of X-rays originated from ordinary sources. It should be noted that the X-ray wafers are only several micrometers thick where those of conventional optical printing processes are 1.5 to 3 mm thick and the feature distortion problem during processing usually worsens with thinner wafers; the precision alignment between exposures in fabricating geometries of high resolutions can be very difficult. The solution is to make wafers of small areas, such as 20x20 cm^2 with distortion smaller than 0.1 μm and no larger wafers will be used, together with the application of the step-and-repeat strategy. At present, this is the focus of international research, the goal, to produce VLSI storage units of 1,000K bits.

The application of X-ray lithography in VLSI-fabrication is still under development and has not yet been introduced into production lines, however, because of its technical and economical advantages, the X-ray lithography, we can predict, will be ready to be used in the high volume production of VLSI within 3 to 5 years.

References

(1) D. L. Spears and H. I. Smith, Electron. Lett. 8, 102 (1972)
(2) M. P. Lepselt, IEEE Spectrum, 18-5, 26 (1981)
(3) US Patents, 4287235
(4) Ma Jun-Ru, The manufacture and Tests of VLSI, 2, 1 (1983)
(5) D. Maydans et al, J. Vac. Sci. Technol., 17-5, 1164 (1980)
(6) G. P. Hughes et al, Electronics, 51-23, 99 (1978)
(7) H. Winick et al, Synchrotron Radiation Research, Plenum Press, New York, Chap. 7, 1980
(8) H. I. Smith et al, J. Vac. Sci. Technol., 17-1, 535 (1980)
(9) G. A. Garrettson et al, Hewlett-Packard J., 8, 14 (1982)
(10) Gu Bo-Chun et al, The manufacture and Tests of VLSI, 1, 14 (1982)

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APPLIED SCIENCES

INPUT SPEED OF FIVE ENCODING METHODS COMPARED

Beijing JISUANJI SHIJIE [CHINA COMPUTERWORLD] in Chinese No 20, 23 Oct 84 pp 1-2

Article: "Chinese Character Encoding Committee of the Chinese Society of Chinese Language Information Evaluates Chinese Character Input Encoding Schemes"]

[Text] The Chinese Character Encoding Committee of the Chinese Society of Chinese Language Information recently held China's first Chinese character encoding scheme evaluation meeting in Shanghai at Jiastong University using a computer to carry out on site testing of five schemes and obtained scientific and objective evaluations. This will have a great impact on determining the most practical Chinese character input encoding schemes in the future.

Chinese character encoding input is an important element in expanding computer applications. In recent years, China's research on encoding of Chinese characters has developed rapidly with many schemes vying for attention, but the appearance of many schemes has also created difficulties for users and manufacturers. Because there is no reliable performance data to serve as a basis, many computer plants are very uncertain when making a decision on what method to use and must adopt compatible methods up to as many as a dozen in some cases which causes considerable waste of manpower and resources.

Thirty graduates with compatible backgrounds from Shanghai middle schools were selected for this test. They all began with no background in encoding and keying operations and after four days of training began the test with the computers. The testing took a total of 20 days. Each person participated in the test one hour per day, and after about 8 days, the encoding error rate for over 90 percent of the people dropped to less than 2 percent, after about 12 days, all had reached an input rate of over 15 characters per minute, with the final top speed of 50 characters per minute. The results show that these schemes are all very good, and with practical training there is still room for improvement.

The five schemes tested in this first batch were all selected on the basis of the self-assessments of the authors. They were: "Bohai-III" by Hu

Xuanhua [5170 1357 5478] et al. of Dalian Institute of Technology, "HPX [Hanzi Ping-Xing [3352 1316 2178 1748] Chinese Character Geometric Formation Scheme" by Li Huiqin [2621 1979 0530] of the Institute of Electronics of the Ministry of Water Resources and Electric Power, "Character Element Encoding" by Wang Zhenqing [3769 2182 3237] et al. of National Defense University of Science and Technology, "Term-Character Binary Geometric Formation Scheme" by Tian Zhixiang [3944 1807 4382] of the Hunal Computing Institute, and "Smart Simplified Code" by Fu Liangwen [2105 5328 2429] et al. of the Institute of Automation of the Ministry of Machine Building-Industry.

INPUT SPEED AND TRAINING TIME FOR CHINESE CHARACTER ENCODING SCHEMES

Seq no	Index / Encoding scheme / Item	Chinese character geometric formation	Bohai-III	Word character binary geometric formation	Chinese character elements	Smart simplified encoder
1	Av 24th day input speed (chars/min)	41.31	35.31	32.24	33.59	35.98
2	Max 24th day input speed (chars/min)	49.53	38.47	36.16	36.21	40.06
3	Low 24th day input speed (chars/min)	30.69	32.76	27.38	30.47	29.27
4	No of days for error rate to drop below 2 percent	8 days	8 days	9 days	6 days	13 days
	(%)	(1.15)	(1.47)	(1.99)	(1.35)	(1.43)
5	No of days of training to reach 15 chars/min	10 days	10 days	12 days	10 days	12 days
6	No of days of training to reach 30 chars/min	19 days	22 days	24 days	23 days	23 days

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APPLIED SCIENCES

HPX [HANZI PIN-XING] INPUT SCHEME DEVELOPED

Beijing JISUANJI SHIJIE [CHINA COMPUTERWORLD] in Chinese No 20, 23 Oct 84 p 6

[Article by Wen Hui [2429 1979]: "An Important Result of Chinese Language Information Processing Work; HPX Chinese Character Geometric Formation Input Scheme Introduced"]

[Text] An advanced Chinese character composer input scheme--HPX [Hanzi Pin-Xing [3352 1316 2178 1748]] Chinese Character Composer Input Scheme--recently passed formal technical appraisal in Beijing and was unveiled to the world.

This scheme was developed by Li Huiqin [2621 1920 [1979?] 0530] of the Institute of Electric Power of the Ministry of Water Resources and Electric Power. It has taken on the advantages of similar schemes, explored a set of superior Chinese character encoding techniques, and used computer aided design. It established a mathematical model and mathematical algorithm for Chinese character encoding on the basis of a great deal of statistical work founded on statistics and combinatorics principles.

The HPX Chinese character geometric information input schemes can process the 6,763 Chinese characters in the GB2312-80 Chinese Character Set (the basic set). Also, an extended set was considered. The average code distance is 3.75 [?]. In the HPX-A scheme, the duplication code is "00" [?]. In the HPX-B scheme, there are 65 pairs of duplication codes (six pairs at level 1, six pairs between levels 1 and 2, with the balance all being level 2 characters). The principles of separation used by this Chinese character encoding scheme basically conform to the generally accepted practices of writing Chinese characters: the method is simple, the rules are compact, and it is easy to learn, easy to remember, and easy to use. The results of the national Chinese character encoding test held by the Chinese Character Encoding Specialized Committee of the Chinese Society of Chinese Language Information in Shanghai in August of this year show that the length of time necessary to learn this system is short, the input speed increases very quickly, non-professional operators can be trained in 20 days, the input speed is 30-50 characters per minute, with the average input speed at 41.3 characters per minute, and in the tests, the miscode rate dropped to less than 2 percent within 8 days.

The specialists who participated in this evaluation felt that this scheme was very scientific, that it was superior overall in a number of indices, that it

was at an advanced level among current domestic and foreign Chinese character composer encoding schemes, and that it should be extended to and used on computer systems as quickly as possible. They also hoped that the keyboard arrangement would be further improved, the number of character roots would be further reduced, that the memory load would be reduced, and that the keyfinding speed would be improved to make it easier for users.

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APPLIED SCIENCES

ROLE OF MOBILE COMMUNICATIONS IN CHINA'S FOUR MODERN ATIONS

Beijing DIANZI XUEBAO [ACTA ELECTRONICA SINICA] in Chinese No 4, 1983 pp 38-43

[Article by Hu Siyi [5170 1835 4135], Director of Chinese Institute of Electronics: "Give Full Play to the Role of Mobile Communications in China's Four Modernizations Drive"]

[Text] Abstract: This paper briefly described the background of the development of mobile communications and explained its significance in China's four modernizations drive by giving examples. Some views on the further development of mobile communication technology in China were also presented.

Introduction

The significance of "Communications" in social advancement and economic development as well as its role in the four modernizations, had been elegantly addressed to in a special publication by Comrade Tong Zhipeng [4547 1807 7720], Chairman of the Communications Division of the Chinese Society of Electronics. In this paper, we will only discuss the function of radio mobile communications and its development based on the needs of the four modernizations.

In view of the fact that the scope of "mobile communications" is very wide, and new contents are continuously made available with rapid development in electronics, this paper will be limited to the following conditions: 30-100CMHz radio frequency bands, mobile ground users, direct real time language communications with targets in various ranges. Its importance to the four modernizations is obvious since time is life and timing is equivalent to economic benefit.

Background of Development

From the development process of communication technology, mobile communication as described in this paper is a natural evolution based on the conventional point-to-point communications. Before World War II, this type of communication primarily relied on medium- and short-wave

radio stations carried on a person's back or installed on vehicles. During World War II, because short-wave stations could not operate without interference especially at night in tropical areas and the availability of frequency bands was limited. It was natural to develop the ultra short wave FM station which had stronger interference resistance and relatively abundant frequency bands to ensure continuous operation day and night to transmit radio wave in sight. Consequently, military mobile communications was first rapidly developed. As the semiconductor integration technology grew so rapidly, a large number of light weight, compact portable, hand-held, or headphone type of ultrashort wave and shorter wavelength FM stations became available. The single-sidebandization and miniaturization of medium- and short-wave stations as well as the availability of digital technology not only enabled the widespread use of point-to-point mobile communications by military and civilian sectors but also created mobile communication networks for various specific applications. Individual users or an entire country can have a region- or nation-wide wired communication network.

The first mobile communication network was built in 1946 in the U.S. After 10 years of development effort, it was not until 1955 or 1956 that they began to use the manual channel switching mobile communication system operating at 150 MHz and 450 MHz. The so-called improved mobile telephone systems, such as the MJ(150MHz) and MK(450MHz) series by IMPS which were capable of choosing channels automatically, were put in operation approximately 10 years later in 1964 and 1969. The central station of these systems employs four transmitters. The loss in output power for each transmitter is 6 dB after going through two 3 dB couplers. If we take the 4.7 dB loss due to the duplexer for a system whose transmitting and receiving frequency gap is 10 MHz (based on the temporary Chinese regulation for the 450 MHz band) into account, the power transmitted by the antenna is only 8.5 W when the power output at the last stage of the transmitter is 100 W. This approach to increase power consumption instead of raising the antenna and its gain was rational at the time. However, it is very difficult to increase the channel number and the capacity is naturally very limited. If eight transmitters are used, the coupling loss will be 9dB. If 16 transmitters are used, then it will be 12 dB. If we take the duplexer loss into account, then 98 percent of the power output of each transmitter will be lost. This inherent defect was difficult to overcome which drove people to search for new solutions.

In the late 1970's, the U.S. and Japan developed a new generation of radio mobile network operating at 850 MHz. In the U.S. it is called the advanced mobile telephone system AMPS and in Japan it is called the Mt-800-M system. These systems not only have specially designed shared antenna for all the transmitters to maintain the coupling loss of each transmitter to 4-6 dB even when 16 or 32 transmitters are used, but also have wider gaps between transmission and receiving (45 MHz for AMPS and 55 MHz for MT-800-M from its original value of 30 MHz) to significantly reduce the

duplexer loss. Furthermore, the interference resistance of the system is also improved. Radio mobile telephone networks thus built represent the highest level practical systems.

Because the operating frequency band is higher than 30MHz barriers such as mountains usually cannot be removed by ground mobile installations. This is a major difficulty in mobile communications. The U.S. is studying the use of satellite communications to expand the function and servicing range of the ground network, which is a feasible way to overcome this difficulty. Once it becomes practical, we not only can overcome mountains but also oceans. It only takes an instance to reach either a foot or a thousand miles.

There is no question about the military value of ground mobile communication networks. A new generation of systems has been successfully developed, such as the Rita system developed jointly by France, Belgium and West Germany and the "grouse" system specifically developed by Britain for its troops stationed in West Germany. They have far superior capabilities over civilian systems. They can transfer and exchange digital information such as dialogues, reports, data and fadsimile. The U.S. is making a large investment on the development of triforces tactical communication network (Tri-Tac), which also includes communications in air and at sea. The technology adopted is even more advanced. There will be more and wider frequency bands and communication installations. The design objective initially includes both digital and analog systems in order to accomodate the fact that a large number of analog systems already exist. It will eventually be totally digitized, including processing of graphic signals. It is estimated that it will be completed in the 1990's. If such a system is indeed materialized, it will have excellent security, interference resistance and mobility, and it can be linked to the future strategic communication system in real time and space. It will be a comprehensive communication network capable of handling communications, intelligence, control and command. One should be able to realize that the development of mobile communication network in the U.S. is due to its global strategic need as a super power.

It can be expected that the technical accomplishments in the military mobile communication network will affect civilian systems.

Mobile Communications Urgently Needed in Four Modernizations

Since the founding of our government, the Chinese telecommunication industries have already supplied mobile radio communication equipment to various departments in transportation, geology, meteorology, energy, politics and law, capital construction, industries and mines, scientific research, and even education and health. It has been effective so far. However, what we can supply has a wide gap as compared with what society needs or with the world standard. In certain areas, the gap is very large. There are many reasons for this to happen. Presently, we feel that the first problem to solve is to let the management in departments in the development, production and promotion of mobile communication

equipment, as well as in departments where such equipment will be used in large quantity, know the significance of mobile communications in the four modernizations. In this section, we will list some familiar examples to explain the importance of developing a mobile radio communication network which suits China's needs and will eventually be linked to other networks. For example:

A command station for communications must be installed on a drilling platform in offshore drilling so that a work group network can be dispatched with hand-held radios or beepers. All the personnel can talk to one another on their posts by installing voice switches and directional microphones on hand-held radios. The device can be put in the coat pocket and the antenna installed on the helmet.

The conversation between an offshore oil field and a moving supply ship, a helicopter, or workers on land, as well as with workers for inland through a land station, can be realized in real time by the appropriate communication equipment.

The daily operation of inland oil fields, large scale construction sites, large industries and mines, harbors and large stations can be regulated accordingly.

The timely response to abnormal phenomena and the monitoring of oil and gas pipelines, as well as the maintenance of power lines, electrified railroad equipment and unattended apparent distance microwave communication relay stations with mobile radio communication systems cannot be replaced.

For an official sitting in a car, to be able to conduct public or private business with another person at a fixed place or sitting in a car is the key to effectively improve modern political and economic lives. Systems similar to the U.S. AMPS system and the Japanese Mt-80-M system were rapidly developed based on such needs. The "information society" naturally cannot do without such a ground mobile telephone system. In many developed countries, such a system has already been connected to existing telephone lines, creating a long range mobile communication network. Its significance in coordinating the social and economical growth in a nation or an area is not difficult to imagine.

It is absolutely mandatory for the law enforcement system which is responsible for national security and social order and the customs office which implements the open door policy and deters smuggling to rely on mobile telephone or communication networks to perform their duties.

In case of natural disasters such as flood, fire and earthquake, especially when the conventional communication networks are destroyed, the consequence will be totally different whether a mobile communication network can be placed in operation. China has learned many lessons in this area. We should refer to some technologies already developed in other countries.

Many culture and art groups in China use pen type transmitters (known as wireless microphone) in larger scale performance to enhance the artistic effect. It is a wireless system whose transmitting power is less than 0.001W. It also belongs to the mobile radios network family.

In terms of military applications, its importance is not difficult to comprehend based on the fact that mobile radio stations are being equipped at the squad or combat group level.

The "paging" system developed in the 1970's added a special function to the telephone network. If you happen to be out when someone tries to call you, this radio paging device can automatically switch this message to a radio paging transmitter to transmit your phone number. If you wear a corresponding receiver (or a beeper), it will ring. The person can call a nearby information desk to inquire the number of the other party. New beeps can also display the telephone number of the other party. CCIR regulations require that beepers should not have any transmitting capability. It is not appropriate to use beepers in certain areas of China where telephone service is limited. It will not be valuable for large plants and mines, hospitals, schools, and offices to have their own internal paging systems to improve the working efficiency. The volume of sales and number of users for mobile communication devices with the aforementioned functions are high on the list in the category of "communications equipment." The future trend is still upward.

Technically, China essentially has the ability to develop such mobile telephone systems.

Investigating Several Engineering Technical Problems

1. Strengthening the Study on Ground Mobile Communication Wave Propagation Characteristics.

The mobile communication channel is a fast attenuating time varying channel. In addition to vehicle speed and operating frequency the attenuation frequency is also related to the multipath effect caused by the reflection and scattering of electromagnetic wave by the obstacles within a few to several dozen meters from the mobile station, as well as the slower changes caused by the path shadow due to the terrain. This type of characteristic parameters must be obtained on site in order to design such equipment. This work is very poor in China. Even in some very large cities, there is a lack of useful data on the wave propagation characteristics and the noise interference level. The relevant authority should make the proper arrangement as we plan this development work.

2. Designing Practical Common Antenna for Transmitters

We should be able to refer to the common antenna technology used by the AMPS system in the U.S. and the MT-800-M system in Japan. We should accelerate the development of a practical common antenna suitable for

operation at 450 MHz. If the frequency gap between transmission and receiving can be further enlarged by design, the plug-in loss can be further reduced and its attenuation resistance is also improved. As long as it is properly designed, the coupling loss of a common antenna for four transmitters can be lowered to 2 dB. The spacing between transmitters can reach 31 dB. These targets can be met if we devote more effort in the technology.

3. Improving Intermodulation Characteristics

Improving the intermodulation between transmitters and receivers has always been a research topics for the design people. The intermodulation problem at 150 MHz has already become very serious in many large cities in China. In addition to adopting effective technical measures to improve the intermodulation between transmitters and receivers, it is necessary to systematically develop the 450 MHz and 900 MHz frequency bands.

4. Networking Mobile Control Stations and Mobile Stations

The central station needs to add a control station, which is equivalent to an integrator in a wired network, in order to allow a mobile telephone network user to locate another wired or wireless user through an appropriate exchange, as well as to realize the real time transfer and exchange of information and command and to monitor mobile stations. Such a mobile control station can manage several neighboring central stations. In view of the current situation that there are many special networks, we can use existing exchanges to separate them from the mobile control station in order to adapt to the temporary wire channel storage in China. Furthermore, the exchange only needs to be minimally modified.

5. Effective Radius of Dedicated Network

The effective radius of a dedicated network, which is primarily a single network, may be slightly larger. However, there may be blind spots such as cliffs and tunnels once the radius is large. If the blind spots are limited, they can be ignored. However, if a bond spot is at a crucial position, it can be remedied by setting up an euxiliary station to cover it by a directional antenna.

6. Sychronization

This is a problem to be encountered and solved in building up a digital mobile communication network. Related departments in China have already accumulated a lot of experience in digital microwave scattering communication systems for future reference.

7. Possible Ways to Solve Channel Congestion

In developing capitalist countries, self-contained super ground mobile networks are being built in addition to various existing telephone networks owing to political and economic competition. Even when certain

local networks are destroyed, nationwide and even worldwide communications are still possible. Presently, their 450 MHz frequency bands are already very congested. It is predicted that the 900 MHz frequency bands will also become crowded. Developing new 1200 MHz frequency bands and exploiting narrow frequency band communications are considered to be current development subjects.

In the research of narrowing frequency width, British researchers suggested the use of a 12.5 kHz frequency for FM stations. However, both theory and experiment showed that the technical performance of this type of station is not as good as the existing 25 kHz frequency gap. Furthermore, we must pay a price to raise the frequency stability by three times, which is not feasible. In recent years, some British researchers proposed the use of a 5 kHz frequency gap single-sided band format for 450 MHz frequency bands. Initially, the Americans opposed this idea and believed that the voice quality would be poor. The British offered the following evaluation after over one year of testing that the performance is best in the 25 kHz frequency gap FM format, the 5 kHz single-sided band format is next, and the 12.5 kHz FM format is the worst. If an amplitude compression and expansion technique is used in the aforementioned single-sided band format, the quality of voice can be improved. Later, the Americans also reached the same conclusions in their own experiments. However, they also pointed out that if a language processing method, i.e. an emphasized and deemphasized measure, is added to the single-sided band equipment for the FM format then the voice quality in the 5 kHz gap single-sided band format can be chastically improved (just as the FM stations using the language compression and expansion technique to improve the voice quality). Moreover, the signal to noise ratio can be also improved. Therefore, they withdrew their original opinion in the CCIR meeting in 1981 and expected to find answers in future experiments.

This type of process can also be tested in other frequency bands. According to our experience, even without any language processing measures on a single-sided band machine, the gain is slightly larger than that of a FM station whose frequency gap is 25 kHz, band width is 16 kHz and maximum frequency deviation is ± 5 kHz.

The installation of a voice switch on the quasi-two way communication equipment to realize the fully two-way conversation at the same frequency can effectively save the frequency spectrum. This is because one syllable of a natural language is approximately 300-500 ms and the opening of an electronic switch consumes 30-50 ms. The listener will not feel any loss of information.

Conclusions

A great deal of work needs to be done to convert the understanding of the importance of mobile communications in the four modernizations to suitable products. The two key links to grasp at the present moment are to reform and to expand the scope of applications. For the former,

product development plans must be drawn according to the needs and desires of the users based on systems engineering methods. The scheduling must be determined according to the manpower, materials and financial capabilities. Practical and feasible technical plans can be formulated on the basis of proven technical viewpoints. Based on the principle of consistent social and economic benefit, we should formulate a technical policy which is capable of mobilizing the enthusiasm of the technical staff in order to reduce the development cycle at the lowest cost through a combination of self-design, imitation, and technology imports. We should make the development departments and production plants voluntarily obey rules drafted to produce high quality products. These management items should be realized through scientific rules and regulations, instead of momentary instincts of the leadership.

As for the latter, the main thing is to let the communication industries establish a market concept to replace a seller's market by a buyer's market. This not only involves attracting users to participate the entire process from development planning to production, but also more importantly their costs can only be effectively reduced if they are widely used. Furthermore, applied research and technological development can be forcefully promoted by the economical and technical information feedback from the users. Consequently the maximum economical benefit can be obtained.

We have already had the technological base necessary for the development of a new generation of mobile communication systems. Further collaboration by departments in scientific research, production, end usage and teaching can definitely make more contributions.

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APPLIED SCIENCES

ENGINEERING MODEL FOR MULTICOMPONENT, REVERSIBLE REACTION NETWORK

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[Text] Abstract

The treatment of a multicomponent reversible reaction network is usually very complicated because of the difficulties encountered in accurately measuring a large number of rate constants as well as in the calculation based on those rate constants. In order to reduce the number of degrees of freedom, the authors presented a method in which the reactor and the separator were considered as a whole. Based on this method, an N-component reversible reaction system might be treated as a two-component system, which made the measuring of rate constants simple and feasible. Simple and explicit expressions for rate constants have been derived for both lumped and distributed reaction systems for first-order reactions, respectively.

I. Introduction

In developing a new 2-chlorobutadiene production process, we encountered the isomerization reaction among the three isoners of dichlorobutene. These isomers can be mutually transformed. Therefore, there are six reactions in total. There are considerable difficulties in measuring these reaction rate constants as well as in employing these rate constants in calculation. For such a multicomponent reversible reaction system, the larger the number of components N is, the more difficult it is to treat.

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In the process of solving this problem, we developed an engineering model for treating a gereralized N-component reversible reaction network. This model is applicable to lumped parameter, as well as distributed parameter, reactors. The number of degrees of freedom is reduced to 1 or 2 as a two-component system by combining the reactor and the separator. Furthermore, very simple expressions could be derived (linear relationship for first-order reaction systems). These expressions could make the measurement of rate constants very simple.

The above described model was experimentally confirmed. A medium-sized testing unit built based on this research result is already operating normally.

The three isomers of dichlorobutene (3,4-dichlorobutene -1, cis-1,4-dichlorobutene -2, and trans-1,4-dichlorobutene -2) can be mutually transformed in the presence of a catalyst. These isomerization reactions can be expressed by the triangle shown in Figure 1. As reported by Besozzi, Tayler and Capp,[1] all reactions are of the first order.

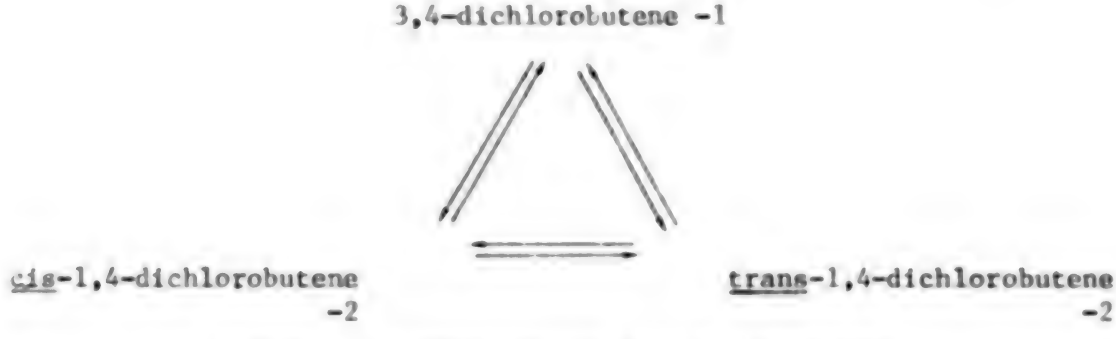

Figure 1. Isomerization of Dichlorobutene

Gene. lly speaking, the above reactions belong to a multicomponent first-order reaction network frequently encountered in petroleum chemistry and in biochemistry. A multicomponent reversible reaction network may be expressed by a triangular or quadrangular structure shown in Figure 2. The combinations of this basic network may also be expressed by the polygonal structure shown in Figure 3. In an N-component reversible reaction system, the maximum number of possible reactions is N(N-1).

Although theoretical difficulties do not exist in the reaction kinetics of an N-component reversible reaction system, however, the treatment is very complex, especially in the accurate determination of a large number of parameters--reaction constants.

On the basis of the unimolecular complex reaction system theory of Wei and Prater,[2] Wei and Kuo[3,4] developed the famous lumping method for a unimolecular reaction system and presented a comprehensive analysis on exact and approximate lumping systems. This theory has already been widely employed in practice.

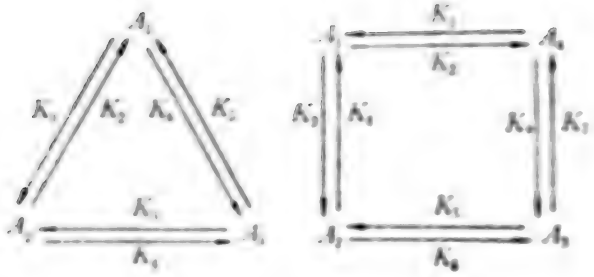

Figure 2. Basic Reaction Network of a Multicomponent System

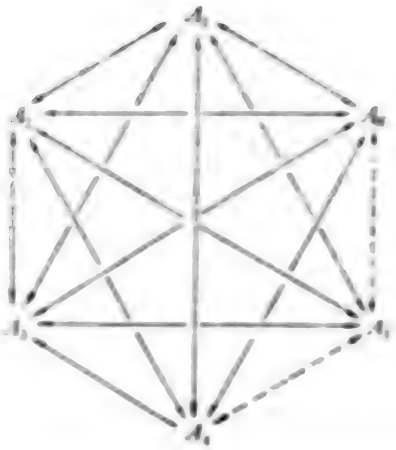

Figure 3. Reaction Network of a Multicomponent System

In this work, an engineering model was presented. According to this model, no matter how many components the actual system has, a complex multicomponent reaction system can be treated as a two-component system under specific conditions (i.e., ideal mixing reactor, multistage serial vessel reactor and piston flow reactor). This method significantly simplified the measuring of kinetic data and the computation process. Very simple expressions were derived for lumped parameter reactor systems, as well as distributed parameter reactor systems.

As shown in Figure 4, the reactor of an N-component system is connected to a separator (e.g., a distillation column) in order to obtain a relatively pure component A_1. Other components are circulated back to the reactor. This is a commonly used engineering process. In Figure 4, C_f, C_r, C_t, and C_p represent the component vectors of feed, return, reactor outlet flow and product in the separator, respectively. In most cases, the separator product is the primary component A_1. Other components will be limited to a certain range.

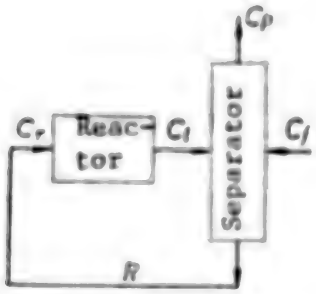

Figure 4. Reactor-Separator Combination To Realize the Multicomponent Reversible Reaction Process

II. System Analysis

First, reactions are assumed to take place in an ideal mixing reactor. For convenience, the concentration of each component in the reactor is expressed by its molecular fraction. The rate constant for each component is

$$r_i = \frac{dC_i}{dt} = f_i(C_1, C_2, \cdots\cdots, C_N) \quad (i = 1, 2, \cdots\cdots N) \tag{1}$$

or

$$r = f(C) \tag{2}$$

where r represents the reaction rate vector and C is the concentration vector. The concentration vector C should satisfy the following normalization condition:

$$\sum_{i=1}^{N} C_i = 1 \tag{3}$$

If the reaction-separation process is considered as a whole, then all components in the feed will be converted into processed products under steady state conditions. In addition to equation (3), the concentrations of all reactants in the reactor will be constrained by the following (N-2) steady state conditions.[5]

$$\frac{r_i}{r_{i+1}} = \frac{\Delta C_i}{\Delta C_{i+1}} = \frac{C_{f,i} - C_{p,i}}{C_{f,i+1} - C_{p,i+1}} = a_i$$

or

$$r_i - a_i r_{i+1} = 0 \quad (i = 2, 3, \cdots\cdots, N-1) \tag{4}$$

where $C_{p,i}$ and $C_{p,i+1}$ represent the concentrations of components i and i+1 in the exit flow of the separator, respectively. If the product from the separator is pure A_1, then $C_{p,i}$ and $C_{p,i+1}$ are zero. There are N independent variable systems (i.e., reactors specified by C) constrained by the normalization condition (3) and steady state conditions (4); therefore, the degree of freedom should be

$$F = N - (N-2) - 1 = 1 \tag{5}$$

Since the degree of freedom is 1, the following equation can be used to express the reaction rate for each component:

$$r = \phi(C_1) \tag{6}$$

For component A_1, we have

$$r_1 = \phi_1(C_1) \tag{7}$$

This is the kinetic equation for a lumped parameter reactor. Regardless of the number of components N, the reaction rate of a component can be expressed as a function of its concentration; just as in a two-component system. Based on

equation (7), a kinetic expression can be obtained by experimentally measuring C_1 and A_1 for industrial applications.

Next, let's assume the reaction takes place in a distributed parameter reactor, i.e., a piston flow reactor. The concentration of each component undergoes infinite changes in the reactor. In other words, there are infinite concentration states in the reactor. However, if the system is analyzed by an integral concept, then there are only two concentration states: inlet and exit.

The reactor inlet and outlet concentrations should satisfy the following conditions:

$$\sum_{i=1}^{N} C_{ri} = 1 \tag{8}$$

$$\sum_{i=1}^{N} C_{pi} = 1 \tag{9}$$

The reaction rate of a component in the reactor may be expressed by the regular differential equation (1). However, there are only (N-1) independent equations because of the normalization equation (3).

If we assume that the initial condition is $C_{(0)} = C_r$, and the duration of stay is T, the reactor exit concentration can be obtained by solving equation (1).

$$C_t = \phi(C_r, T) \tag{10}$$

The amount reacted in the reactor for a component is

$$\Delta C = \phi(C_r, T) - C_r \tag{11}$$

Similar to a lumped parameter system, if the reactor and separator are considered as a whole, all the components fed must be converted to A_1 in the reactor in steady state conditions. Therefore, the inlet and exit concentrations of the reactor are still constrained by (N-2) steady state conditions:

$$\frac{\Delta C_i}{\Delta C_{i+1}} = \frac{C_{pi} - C_{ri}}{C_{r,i+1} - C_{p,i+1}} = a_i$$

or

$$\Delta C_i - a_i \Delta C_{i+1} = 0 \quad (i = 2, 3, \cdots\cdots, N-1) \tag{12}$$

As mentioned before, if the product obtained from the separator is pure A_1, then C_{p1} and $C_{p,i+1}$ are zero.

Because of the constraints by the normalization relations (8) and (9), the (N-1) independent differential equations (1), and the (N-2) steady state conditions, the degrees of freedom of the reaction system as defined by the (2N+1) independent variables (i.e., concentration vectors C_r and C_t as well as retention time T) becomes

$$F = (2N + 1) - 2 - (N - 1) - (N - 2) = 2 \tag{13}$$

In this work, we regard the target product A_1 in the recycling flow with concentration, C_{r1}, and the retention time, T, are regarded as degrees of freedom. Then, the concentration variation of a component at the inlet and outlet of the reactor can be expressed as follows:

$$\Delta C = \bar{\Psi}(C_{r1}, T) \tag{14}$$

The concentration change of component A_1 is

$$\Delta C_1 = \bar{\Psi}_1(C_{r1}, T) \tag{15}$$

The increment of A_1 in the reactor is

$$W_1 = R\bar{\Psi}_1(C_{r1}, T) = R\bar{\Psi}_1(C_{r1}, \frac{V_R}{R}) \tag{16}$$

where R is the recycling flow rate and V_R is the effective volume of the reactor. Hence, the function $\bar{\Psi}_1$ can be found by varying C_{r1} and R experimentally. Therefore, a multivariable problem becomes a two-variable problem. Furthermore, if the separator is sufficiently effective, C_{r1} may approach zero. In this case, it becomes a single variable problem, which further simplifies experimental measurement and data processing.

When all the reactions in the system are first order, simple expressions for the apparent rates can be derived for both lumped and distributed parameter systems. They are described as follows.

The Lumped Parameter Reaction System

Equation (1) may be written as follows for a first-order reaction system

$$r_i = \frac{dC_i}{dt} = -\sum_{j=1}^{N} k_{ij} C_i + \sum_{j=1}^{N} k_{ji} C_j \qquad (i = 1, 2, \cdots\cdots, N) \tag{17}$$

where k_{ij} represents the rate constant for reactant i to form product j. Obviously, $k_{ij} = 0$. The above linear differential equations can also be expressed in a matrix form.

$$r = \frac{dC}{dt} = KC \tag{18}$$

K is the rate constant matrix:

$$K=\begin{bmatrix} -\sum_{j=1}^{N}k_{1j} & k_{21}\cdots\cdots\cdots k_{N1} \\ k_{12} & -\sum_{j=1}^{N}k_{2j}\ \cdots\cdots k_{N2} \\ \vdots & \vdots \quad\quad \vdots \\ k_{1N} & k_{2N}\cdots\cdots -\sum_{j=1}^{N}k_{Nj} \end{bmatrix} \tag{19}$$

Substituting equation (17) into (4), we get:

$$\sum_{j=1}^{N}k_{ji}C_i-\sum_{j=1}^{N}k_{ij}C_i-a_i\left(\sum_{j=1}^{N}k_{j,i+1}C_i-\sum_{j=1}^{N}k_{i+1,j}C_{i+1}\right)=0$$
$$(i=2,3,\cdots\cdots,N-1) \tag{20}$$

Equations (20) and (3) form a group of simultaneously valid (N-1) under linear algebraic equations

$$DC_n = B \tag{21}$$

In the equation, D is a (N-1) order coefficient matrix whose elements are functions of k_{ij} and a_i.

$$C_n=\begin{bmatrix} C_2 \\ C_3 \\ \vdots \\ C_N \end{bmatrix} \qquad B=\begin{bmatrix} 1-C_1 \\ (a_2k_{12}-k_{12})C_1 \\ \vdots \\ (a_{N-1}k_{1N}-k_{1N-1})C_1 \end{bmatrix} \tag{22}$$

The solution of the above linear equation is

$$C_i = \beta_i + \eta_i C_1 \quad (i = 2,3,\cdots\cdots,N) \tag{23}$$

Substituting it into equation (18),

$$r=KC=K\begin{bmatrix} C_1 \\ \beta_2+\eta_2C_1 \\ \vdots \\ \beta_N+\eta_NC_1 \end{bmatrix}=\begin{bmatrix} K_{11}+L_1C_1 \\ K_{12}+L_2C_1 \\ \vdots \\ K_{1N}+L_NC_1 \end{bmatrix} \tag{24}$$

Let us assume that C_1^* is the equilibrium concentration of A_1. When the system's input and output approach zero, i.e., near closed loop recycling, the concentration of A_1 is equal to C_1^*. Under steady state, we must have

$$\mathbf{r} = \mathbf{K}\mathbf{C}^* = 0 \tag{25}$$

to obtain, $$L_i = -\frac{K_{ii}}{C_i^*} \tag{26}$$

Therefore, $$r = K_i\left(1 - \frac{C_i}{C_i^*}\right) \tag{27}$$

For A_1, we get

$$r_1 = K_{11}\left(1 - \frac{C_1}{C_1^*}\right) \tag{28}$$

According to equation (27), K_i can be determined for engineering calculation by measuring the concentration C_1 of component A_1 in the reactor (i.e., the concentration C_{e1} of component A_1 at the exit of the reactor) and the rates of all components.

Now let us consider the situation in a m stage serially connected ideal mixing vessel reactor. Assuming the effective volume of each vessel is equal and the total retention time is T, then the average retention time in each vessel is T/m. In Figure 5, $\mathbf{C}_I$, $\mathbf{C}_{II}$, $\cdots\ \cdots$, $\mathbf{C}_m$ are the concentration vectors from the vessels, respectively. The balance of materials in each vessel is:

$$V_R\mathbf{K}\mathbf{C}_l = R(\mathbf{C}_l - \mathbf{C}_{l-1}) \tag{29}$$

Because $\frac{V_R}{R} = \frac{T}{m}$, therefore

$$\frac{T}{m}\mathbf{K}\mathbf{C}_l = \mathbf{C}_l - \mathbf{C}_{l-1} \tag{30}$$

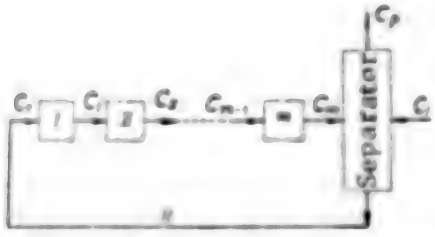

Figure 5. Multicomponent Reversible Reactor Process in a m Stage Serial Reactor-separator System

Due to the normalization conditions, the differential equation expressed by (17) and (18) only has (N-1) independent equations. Because the order of K is (N-1), therefore, one characteristic root is 0. Let the characteristic roots of the matrix K be $\lambda_1 = 0, \lambda_2, \lambda_3, \cdots\ \cdots, \lambda_N$ and the characteristic vector matrix be P, then $\mathbf{K} = \mathbf{P}\Lambda\mathbf{P}^{-1}$ where $\Lambda = \text{diag}\ (0, \lambda_2, \lambda_3, \cdots\ \cdots, \lambda_N)$. Hence,

$$\frac{T}{m}P\Lambda P^{-1}C_i = C_i - C_{i-1}$$

$$C_i - \frac{T}{m}P\Lambda P^{-1}C_i = C_{i-1}$$

$$C_i - P\left(\frac{T}{m}\Lambda\right)P^{-1}C_i = C_{i-1}$$

$$P\left(I - \frac{T}{m}\Lambda\right)P^{-1}C_i = C_{i-1}$$

Therefore,

$$C_i = P\left(I - \frac{T}{m}\Lambda\right)^{-1}P^{-1}C_{i-1} \tag{31}$$

using this iteration equation, we get

$$C_1 = P\left(I - \frac{T}{m}\Lambda\right)^{-1}P^{-1}C_0$$

$$C_2 = P\left(I - \frac{T}{m}\Lambda\right)^{-1}P^{-1}C_1$$

$$= P\left(I - \frac{T}{m}\Lambda\right)^{-1}P^{-1}C_0$$

.....

$$C_m = P\left(I - \frac{T}{m}\Lambda\right)^{-m}P^{-1}C_0$$

$$G_m(T) = P\left(I - \frac{T}{m}\Lambda\right)^{-m}P^{-1} \tag{32}$$

Let

$$= \begin{bmatrix} g_{11}(T) & g_{12}(T) \cdots\cdots g_{1N}(T) \\ g_{21}(T) & g_{22}(T) \cdots\cdots g_{2N}(T) \\ \vdots & \vdots \qquad\qquad \vdots \\ g_{N1}(T) & g_{N2}(T) \cdots\cdots g_{NN}(T) \end{bmatrix} \tag{33}$$

All the elements in $G_m(T)$ are determined by the rate constant matrix K, the number of stage of the serial reactor m, and the average retention time T. Substituting equation (33) into (32) we get

$$\boldsymbol{C}_m = \boldsymbol{G}_m(T)\boldsymbol{C}_r = \begin{Bmatrix} \sum_{i=1}^{N} g_{1i}(T)C_{ri} \\ \sum_{i=1}^{N} g_{2i}(T)C_{ri} \\ \cdots\cdots\cdots \\ \sum_{i=1}^{N} g_{Ni}(T)C_{ri} \end{Bmatrix} \tag{34}$$

Therefore, the concentration increase of a component after passing through m reaction stages can be expressed as:

$$\Delta\mathbf{C} = \mathbf{C}_m - \mathbf{C}_r = [\boldsymbol{G}_m(T) - \boldsymbol{I}]\mathbf{C}_r \tag{35}$$

From the normalization and steady state conditions, we can obtain the following (N-1) linear equations:

$$\sum_{i=2}^{N} C_{ri} = 1 - C_{r1} \tag{36}$$

and

$$\sum_{i=2}^{N} g_{ji}(T)C_{ri} - C_{rj} - a_j\left[\sum_{i=2}^{N} g_{j+1,i}(T)C_{ri} - C_{r,j+1}\right] = a_j g_{j+1,1}(T)C_{r1} - g_{j1}(T)C_{r1} \quad (j = 2, 3, \cdots\cdots, N-1) \tag{37}$$

Combining equations (36) and (37), we get

$$\boldsymbol{D}\begin{Bmatrix} C_{r2} \\ C_{r3} \\ \vdots \\ C_{rN} \end{Bmatrix} = \begin{Bmatrix} 1 - C_{r1} \\ [a_2 g_{11}(T) - g_{21}(T)]C_{r1} \\ \cdots\cdots\cdots\cdots \\ [a_{N-1}g_{N-1,1}(T) - g_{N-1,1}(T)]C_{r1} \end{Bmatrix} \tag{38}$$

D is a (N-1) order coefficient matrix determined by K, a, T and m.

The solution of equation (38) is:

$$C_{ri} = E_i(T)C_{r1} + H_i(T) \quad (i = 2, 3, \cdots\cdots, N) \tag{39}$$

Hence, the concentration increase of a component after m reaction stages is

$$\Delta\boldsymbol{C} = [\boldsymbol{G}_m(T) - \boldsymbol{I}]\boldsymbol{C}_r$$

$$= [\boldsymbol{G}_m(T) - \boldsymbol{I}] \begin{Bmatrix} C_{r1} \\ E_1(T)C_{r1} + H_1(T) \\ \cdots\cdots\cdots \\ E_N(T)C_{r1} + H_N(T) \end{Bmatrix}$$

$$= \begin{Bmatrix} M_1(T)C_{r1} + K_{m1}(T) \\ M_2(T)C_{r1} + K_{m2}(T) \\ \cdots\cdots\cdots \\ M_N(T)C_{r1} + K_{mN}(T) \end{Bmatrix} \tag{40}$$

If the operation is close looped (i.e., $C_{r1} = C_1^*$), it is necessary that $\Delta C=0$. Therefore,

$$M_i(T) = -\frac{K_{mi}(T)}{C_i^*} \qquad (i = 1, 2, \cdots\cdots, N) \tag{41}$$

Substituting equation (41) into (40), we get

$$\Delta \boldsymbol{C} = \boldsymbol{K}_m(T)\left(1 - \frac{C_{r1}}{C_1^*}\right) \tag{42}$$

For component A_1, we have

$$\Delta C_1 = K_{m1}(T)\left(1 - \frac{C_{r1}}{C_1^*}\right) \tag{43}$$

IV. Distributed Parameter Reaction System

As mentioned before, when the reaction is carried out in a piston reactor, there are infinite concentration states in the reactor. Hence, it is difficult to obtain a simple differential expression. However, if it is treated by an integral form, then there are two concentration states at the inlet and exit. The problem can be drastically simplified. Therefore, we will focus on the integral expression of the kinetics of a distributed parameter reaction system.

The reaction kinetic equation of a two-component first-order reversible reaction system can be expressed in an integral form as:

$$\Delta C_1 = \frac{k_1}{k_1 + k_2}\left[1 - e^{-(k_1 + k_2)T}\right]\left(1 - \frac{C_{10}}{C_1^*}\right) \tag{44}$$

where k_1 is the forward reaction rate constant, k_2 is the reverse rate constant, and C_{10} is the A_1 concentration at the reactor inlet. Equation (44) may also be simplified as:

$$\Delta C_1 = K(T)\left(1 - \frac{C_{10}}{C_1^*}\right) \tag{45}$$

The authors wish to prove that the kinetic integral expression for the aforementioned N component reaction system may also be expressed by a formula similar to equation (45) for a two component system when the reactor and separator are considered as a whole.

The reaction rate equation of an N component reversible reaction system may be expressed by equation (18):

$$\frac{d\mathbf{C}}{dt} = \mathbf{K}\mathbf{C}$$

Now we know that the initial concentration state at the reactor inlet is $\mathbf{C}(0) = \mathbf{C}$. From the previous section we know that $\mathbf{K} = \mathbf{P}\Lambda\mathbf{P}^{-1}$. Let $\mathbf{Y} = \mathbf{P}^{-1}\mathbf{C}$, then equation (18) becomes

$$\frac{d\mathbf{Y}}{dt} = \Lambda\mathbf{Y}$$

and

$$\begin{bmatrix} \dot{Y}_1 \\ \dot{Y}_2 \\ \vdots \\ \dot{Y}_N \end{bmatrix} = \begin{bmatrix} 0 & 0 \cdots\cdots 0 \\ 0 & \lambda_2 \cdots\cdots 0 \\ \vdots & \vdots \quad\quad \vdots \\ 0 & 0 \cdots\cdots \lambda_N \end{bmatrix} \begin{bmatrix} Y_1 \\ Y_2 \\ \vdots \\ Y_N \end{bmatrix} \tag{47}$$

The solution of equation (47) is

$$\begin{bmatrix} Y_1(t) \\ Y_2(t) \\ \vdots \\ Y_N(t) \end{bmatrix} = \begin{bmatrix} Y_1(0) \\ e^{\lambda_2 t} Y_2(0) \\ \vdots \\ e^{\lambda_N t} Y_N(0) \end{bmatrix} \tag{48}$$

or

$$\mathbf{Y}(t) = \mathbf{Q}(t)\mathbf{Y}(9) \tag{49}$$

where,

$$\mathbf{Q}(t) = \begin{bmatrix} 1 & 0 \cdots\cdots 0 \\ 0 & e^{\lambda_2 t} \cdots\cdots 0 \\ \vdots & \vdots \quad\quad \vdots \\ 0 & 0 \cdots\cdots e^{\lambda_N t} \end{bmatrix} \tag{50}$$

Because $\mathbf{Y} = \mathbf{P}^{-1}\mathbf{C}$ and $\mathbf{C}(0) = \mathbf{C}$, therefore

$$\mathbf{Y}(0) = \mathbf{P}^{-1}\mathbf{C}_r, \tag{51}$$

$$\mathbf{Y}(t) = \mathbf{Q}(t)\mathbf{P}^{-1}\mathbf{C}_r \tag{52}$$

$$\mathbf{C}(t) = \mathbf{P}\mathbf{Q}(t)\mathbf{P}^{-1}\mathbf{C}_r \tag{53}$$

Assuming the retention time in the reactor is T, then the concentration vector at the exit of the piston reactor is:

$$C_t = PQ(T)P^{-1}C_r \tag{54}$$

Let $G(T) = PQ(T)P^{-1}$, then $C_t = G(T)C_r$ (55)

Using a derivation similar to the one used in the previous section for equations (34) to (43), we get

$$\Delta C = K_D(T)\left(1 - \frac{C_{r1}}{C_1^*}\right) \tag{56}$$

For component A_1, we get

$$\Delta C_1 = K_{D1}(T)\left(1 - \frac{C_{r1}}{C_1^*}\right) \tag{57}$$

which has a form similar to equation (45). $K_D(T)$ is determined by the rate constant matrix K, the ratio of the concentration ratio of a component in the feed and the product α, and the retention time in the reactor T.

A piston flow reactor may be considered as a special case of a serial vessel reactor with infinite number of stages. Therefore, the above result may also be obtained from the multivessel reactor derivation in the last section. When $m \to \infty$, equation (32) becomes

$$C_r = \lim_{m\to\infty} P\left(I - \frac{T}{m}\Lambda\right)^{-m} P^{-1}C_r$$

$$= P\begin{bmatrix} \lim_{m\to\infty} 1^{-m} & 0 & \cdots & 0 \\ 0 & \lim_{m\to\infty}\left(1 - \frac{T}{m}\lambda_2\right)^{-m} & \cdots & 0 \\ \vdots & \vdots & & \vdots \\ 0 & 0 & \cdots & \lim_{m\to\infty}\left(1 - \frac{T}{m}\lambda_N\right)^{-m} \end{bmatrix} P^{-1}C_r$$

$$= P\begin{bmatrix} 1 & 0 & \cdots & 0 \\ 0 & e^{\lambda_2 T} & \cdots & 0 \\ \vdots & \vdots & & \vdots \\ 0 & 0 & \cdots & e^{\lambda_N T} \end{bmatrix} P^{-1}C_r$$

$$= PQ(T)P^{-1}C_r$$

$$= G(T)C_r$$

which is equation (55).

According to equation (57), the increase of A_1 in the reactor is:

$$W_1 = R\Delta C_1$$

$$= RK_{D1}(T)\left(1 - \frac{C_{r1}}{C_1^*}\right)$$

$$= RK_{D1}\left(\frac{V_R}{R}\right)\left(1 - \frac{C_{r1}}{C_1^*}\right) \tag{58}$$

If the effective volume of the reactor V_R remains constant, then the above formula may be expressed as

$$W_1 = K'_{D1}(R)\left(1 - \frac{C_{r1}}{C_1^*}\right) \tag{59}$$

because of the effect of V_R, and K'_{D1} and K_D have different functional types. We can change R to experimentally find K'_{D1} (R) from equation (59). It should be pointed out that K_{D1} and K'_{D1} are not only determined by the characteristics of the reactor and separator, but also by the operating conditions; i.e., the concentration difference ratio of each component at the inlet and exit of the system.

Even when the rate constants have already been measured by other methods,[2,6] the kinetic expression of the process can still be organized in the above form. Thus, a complex iteration process may be avoided in the optimization calculation.

For multicomponent reaction system which is not completely reversible, as long as it does not contain any terminal components unable to be converted to other components as well as serial irreversible steps with identical rate constants, Wei and Prater[2] pointed out that it is completely comparable to a kinetically reversible system without any new characteristics.

Therefore, the method developed in this work is also applicable to this type of reaction system.

V. Conclusions

By regarding the reactor and separator as a whole, the treatment of an N component reversible reaction system was greatly simplified. Regardless of the number of components, the degree of freedom of a lumped parameter reactor is always 1. For a distributed parameter reactor the degree of freedom is 2. According to the analysis, all the reaction rate constants in a lumped parameter reactor can be expressed as functions of the concentration of A_1. It means that the determination of a rate constant is only related to one variable. In a distributed parameter reactor, the concentration increment of a component may be expressed as a function of the concentration of A_1 in the recycling flow and the retention time. This function can be experimentally determined for a non-first order reaction system.

The method in this work is not limited to a process in which only one component is the target product. Of course, if component A_1 is the only desired product and relatively pure A_1 can be obtained from the separator, then $C_{pi}=0$ ($i\neq 1$) in equations (14) and (12). The problem will become even simpler. If there is more than one product in the process, various numerical values of a_i may be chosen based on the process.

When all the reactions in the system are first order reactions, very simple explicit formulas may be derived for an ideal mixing reactor, a piston flow reactor, and a multistage serial vessel reactor. The kinetic equations are linear. By plotting r_i vs $(1-\frac{C_i}{C_i^*})$ or ΔC_i vs $(1-\frac{C_{ri}}{C_i^*})$ measured experimentally in rectangular coordinate system, the model parameters K_{Li} or $K_{Di}(T)$ can be obtained.

The authors confirmed the derivation in this work by studying the dichlorobutene isomerization-separation system in a continuously stirring vessel reactor-distillation column system. Furthermore, the process was successfully scaled up.

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List of Symbols

A_i -- ith component

B -- vector expressed by equation (22)

C_i -- concentration of the ith component, molar fraction

C -- concentration vector

D -- coefficient vector in equations (21) and (38)

F -- degrees of freedom of the system

$G(T)$ -- $G(T)=PQ(T)P^{-1}$.

$G_m(T)$ -- $G_m(T)=P\left(I-\frac{T}{M}\Lambda\right)^{-m}P^{-1}$.

I -- unit matrix

i,j -- component symbols

K_{Li} -- apparent rate constant of the ith component in a lumped parameter system

K_L -- apparent rate constant vector in a lumped parameter system

K_{Di} -- apparent rate constant of the ith component in a distributed parameter system

K_D -- apparent rate constant vector in a distributed parameter system

K -- rate constant to produce component j from i

N -- number of components in the system

P -- characteristic vector matrix of the matrix K

$Q(T)$ -- matrix expressed by equation (50)

R -- recycling flow rate

r_i -- reaction rate of the ith component

r -- reaction rate vector of a component

T -- retention time of stay in the reactor

V_R -- effective volume of the reactor

W_i -- increment of the ith component in the reactor

Y -- $Y = P^{-1}C$

α_i -- concentration ratio of the ith and i+1th components in the feed

α -- concentration ratio vector of components in the feed

Λ -- $\Lambda = \text{diag}\ (\lambda_1, \lambda_2, \cdots \cdots, \lambda_N)$

λ_i -- ith characteristic root of the matrix K

$*$ -- equilibrium composition

REFERENCES

1. Bessozzi, A.I., Tayler, W.H. and Capp, C.W., "The Commercial Production of Chlorprene Via Butadiene" Symposium on Advances in Petrochemical Technology, presented before the Division of Petroleum Chemistry Inc, E15, American Chemical Society New York Meeting, August, (1972).

2. Wei, J. and Prater, C.D., ADVANCES IN CATALYSIS, Vol 13, p 202, 1962.

3. Kuo, J. and Wei, J., IND. ENG. CHEM. FUNDAM., Vol 8, p 114, 1969.

4. Wei, J. and Kuo, J., IND. ENG. CHEM. FUNDAM., Vol 8, p 124, 1969.

5. Chen Mincheng, Yuan Weikang and Lu Renjie [7120 0088 2638], KEXUE TONGBAO [SCIENCE BULLETIN], Vol 23, p 737, 1978.

6. Chang, F.W., IND. ENG. CHEM. PROCESS DES DEV., Vol 16, p 59, 1977.

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APPLIED SCIENCES

DEVELOPMENT, PROSPECT OF SATELLITE DYNAMICS DISCUSSED

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[Article by Huang Kunyi [7806 0981 0308] of Zi jinshan Observatory, Chinese Academy of Sciences: "Development and Prospect of Satellite Dynamics"]

[Text] Since earth satellites were launched, celestial mechanics is no longer a science that intrigues a small number of astronomers and mathematicians. It has become a special engineering technology. Because of the rapid development in space exploitation and satellites, the availability of new observation techniques, the in-depth study of the earth and its surrounding environment, the application of large high speed computers and the penetration by other disciplines, a new frontier science-satellite dynamics has begun to emerge on the basis of celestial mechanics.

Satellite dynamics is the science of studying the laws of motion of orbiting satellites under the influence of various mecahnical factors. It includes the tracking of satellite orbit, analysis of perturbation sources, study of laws of satellite motion, determination of satellite orbit, processing of satellite data and application of satellite dynamics.

I

Satellite dynamics is directly serving the development of various series of satellites. It has a strong practical and application oriented nature from its inception.

Since the USSR launched its first satellite in 1957, 17 countries and organizations in the world have launched a total of 3,000 satellites. They are conducting military missions such as communications, missile warning, photographic reconnaissance, electronic surveillance, navigation, ocean surveillance, military meteorology, nuclear explosion detection and interception satellite, as well as scientific research tasks such as astronomical exploration, geophysical environment detection, weather, survey of earth resources, geodetic survey, broadcasting, and planetary exploration. Furthermore, there are manned space missions. Because of different missions, the height, dipangle and eccentricity of each satellite are different. For example, low orbit satellites 200-300 kilometers above ground are mostly for military reconnaissance missions. They are close to

the earth in order to "see" better. However, they are affected by the earth atmosphere, leading to rapid changes in their orbits. Satellites launched for geodetic survey, navigation and exploitation of resources require a more stable orbit. The altitude of this type of satellite is approximately 1,000 km above ground. They are called medium orbit satellite. In addition, there are high orbit satellites more than 10,000 km above, such as geosynchronous satellites and high orbit space exploitation satellites.

Despite the fact that there are many types of satellites, there is a common fundamental requirement. A satellite must be tracked to determine its orbit according to the accuracy required in order to ascertain the position of the satellite at a specific moment. As the satellite series further develops, this requirement is becoming more stringent. For example, in order to measure the wind speed, especially the wind speed and cloud pattern on the ocean, the accuracy of the sub-satellite point (projection of satellite on the earth) of a weather satellite must be around 10 meters. The orbit of the navigation satellite is used directly to determine the position of a ship. The accuracy of the satellite position must reach the 10 meter order of magnitude. In order to satisfy the accuracy requriements of the earth center coordinate system, the shape of the earth and its gravitational field, the accuracy of the orbit of a geodetic satellite must reach the order of magnitude of im. In order to accurately measure the shape of the ocean surface, the accuracy of the altitude of an ocean survey satellite must reach the decimeter level. The orbiting of certain satellites used in geodynamic studies, such as laser geodetic satellites, has already reached the decimeter level. It is marching toward the millimeter level. For low orbit satellites which are greatly affected by the earth atmosphere and have rapidly varying orbits, the orbiting accuracy are also required to reach 100 or even 10 meters. The orbiting accuracy of a geosynchronous satellite is used as a military warning system or a tracking station for other satellites, its orbiting accuracy must also be significantly improved. Thus, we may conclude that one of the major tasks of satellite dynamics is to continually improve the accuracy of the projected position of an orbiting satellite, which is also one of the major driving forces of satellite dynamics.

The second basic requirement imposed by satellite development on satellite dynamics is to employ the laws of satellite orbiting motion to provide bases for the design of satellite orbits. For example, certain weather satellites, earth resources satellites and photographic reconnaissance satellites are required to survey the same area under indentical natural conditions. This will require the synchronous motion of the satellite orbit to the sun in the celestial sphere, i.e., the so-called solar synchronous orbit. A low earth orbit satellite should minimize its altitude to the extent that it has a satisfactory lifetime. This must either master the laws of satellite deorbiting or adopt a periodically changing orbit in order to lengthen its lifetime. After entering its "fixed point" above the equator, a geosynchronous satellite will gradually drift. Therefore, we must find the drifting pattern in order to take suitable measures to stablilize it. The selection of a satellite launching window is also an important aspect in satellite orbit design. For example, the launching time and orbit of a satellite must be rationally arranged that a series of

satellites can be distributed accordingly in space. For example, the U.S. plans to launch 24 navigation satellites to be placed on three orbital planes 120° apart. There are 8 satellites on the same orbital plane. Thus, a user anywhere in the world can at least see six satellites simultaneously to facilitate navigation and location. As another example, for optical observation of satellites, the satellite flies over the ground observation station it should be dark on the earth while the sun still shines on the satellite. If the launching time is not controlled properly, the useful life of the satellite may also be reduced. Normally a satellite falls as a consequence of atmospheric resistance. Atmospheric resistance decreased the kinetic energy of the satellite to cause its orbit to continuously become smaller until entering the dense atmosphere of the earth and burning off. Despite its 440 km perigee and 40,000 km apogee, the communications satellite "Lightning" launched by the USSR in 1964 fell into the earth atmosphere in less than 1 year because the orbit became flatter due to the relative position of the sun, the moon and the satellite at the time. The study of the laws of relative motion of satellites led to the development of satellite tracking technology. The choice of an optimal orbit and the study of orbit changing have practical and military significance. Recently someone suggested to use liquid crystal to change the light pressure on the satellite to maintain an accurate distance between satellites in order to fabricate a space optical interference telescope.

II

The rapid development in satellite observation technology is another strong driving force behind satellite dynamics. In the past 20 years, new satellite observation techniques continue to emerge. Very frequently before a specific technique is developed to its full potential, another system begins to emerge. Many competitive observation techniques are simultaneously present to measure almost all the relative motion between the satellite and ground observation stations, such as direction, direction variation, directional cosine, satellite distance, satellite speed and distance difference between two instances. In addition, satellite tracking by satellite and satellite altimetry are also possible. The accuracy has improved drastically. Initially the accuracy of satellite position determination was on the order of kilometers and it is on the decimeter to centimeter scale. The number of measurable quantities is very high, collecting tens of thousands and millions of pieces of data. The development of satellite theory often cannot catch up with that of observation. The accuracy in observation has already reached the centimeter scale but orbit fixing on the centimeter level still remains difficult. The advantages and disadvantages of the current observation systems are analyzed below:

Satellite Photographic Observation: It can be approximately divi led into astronomical telescope and trajectory camera, typically represented by Smith-Baker station network and the BC-4 network. This method involves photographing the satellite using the stars as the background to determine the direction of the satellite by the position of the stars listed in the table. The accuracy can reach 0.25-0.50 radians/second. The actual accuracy is approximately 0.50-1.00 radians/second. The accuracy of

determining directional variation is approximately 0.1 radian second. Satellite photographic observation reached its peak in the 1960's. However, due to the complicated data processing procedures, the efficiency is poor. It is even more difficult to further improve its accuracy. It becomes a less favorable technique. However, in the study of the reference coordinate system, it can still be used to determine the "absolute" direction in space. Furthermore, this technique is not limited by the equipment installed on satellites. Therefore, it can be used to observe a variety of them. In addition, although the accuracy of the visual observation technique widely employed in the early stage is low, the equipment and operation, however, are simple. It is still used in satellite tracking and forecasting when the accuracy requirement is not very high.

Satellite Doppler Radio Observation: This technique measures the relative velocity between a satellite and an observation station or the distance difference between a satellite and an observation station at two instances using the Doppler effect. Usually a single Doppler channel, i.e., satellite emitting a fixed frequency signal to be received by the observatin station, is used. Jet Propulsion Laboratory in the U.S. uses a pair of Doppler channels for tracking interplanetary space ships in the deep space, i.e., the observation station emits a fixed frequency signal to be received and amplified by the satellite and then retransmitted to the observation station. Therefore, it can also be considered as a Doppler radar. Doppler observation reached its peak in the late 1960's and 1970's. According to a 1978 statistics compiled abroad, more than 4,000 Doppler receivers were in operation at that time, making great contributions to satellite orbit tracking, satellite navigation, satellite geodesy, and geodynamics. The present observation accuracy is 1-2 cm sec^{-1} (speed) and 10-20 cm (distance difference). If the stability of the oscillators on satellites can be improved and the transmission frequency can be raised to reduce the effect of atmospheric refraction in order to improve the accuracy by a factor of 5-10.

Satellite Laser Ranging: Using laser to measure the distance between a satellite and an observation station began in the mid 1960's. In the past decade, the technology has been developed rapidly. The installation of subnanosecond laser and signal detector, the improvement of the reliability of lasers, and the increasing laser output power improved the accuracy of observation and extended the maximum measurable range. The accuracy is improved to the decimeter scale from the original meter level. The accuracy of the third generation laser has already reached 3-5 cm, working toward the 1 cm target. It has already exceeded that of Doppler observation and has become very effective in the accurate determination of satellite orbit. Its disadvantages are that it is severly limited by weather, only applicable to satellites equipped with laser reflectors, and cost.

Satellite Radar Ranging: There are two basic types--pusle radar and phase radar and both require transponders installed on the satellite. If signals reflected by the satellite are used, the measurable distance will be severely limited. Its accuracy is at best on the order of several dozen meters. This method is powerful. It is not limited by the weather. The

sampling point density can be very high. However, because the equipment is cumbersome, costly and hard to maintain, it is mostly used in military missions and high orbit earth satellite observation. The data can also be used in the study of atmospheric perturbation and in the determination of the resonance coefficient of the earth's gravitational field. Furthermore, this method can be linked to air defense. For example, the phase controlled radar array of the North America Air Defense Command is very effective in the tracking and identification of satellites.

Satellite Radio Interference Measurement: The determination of satellite direction based on the principle of radio interference measurement was a basic method used by the Americans in the early stage. It is represented by small tracking stations. The optimal accuracy is 20 radian second. But it is much lower when the sun is shining intensely. This system is costly, technically complicated and less accurate. Hence, it was not widely used.

Many new interference systems were developed in recent years, including the Mighty Mites system (using low base line interferometer to measure satellite signals) and the SERIES system (using phase antenna array to measure signals from a navigation satellite). The objective of these systems is to determine the coordinates of a point on the ground. The accuracy is reported of the order of magnitude of centimeters.

Since the 1970's, space observation technology has been very rapidly developed. For example, we have satellite tracking satellites (Doppler, laser and laser interference) and satellite altimeters. Satellite tracking satellites expanded the scope of observation. Furthermore, because the radio signal does not go through the troposphere, the effect of atmospheric refraction no longer exists. The accuracy of observation is improved. For example, the Doppler method is used to track satellites to determine the relative velocity between satellites at an accuracy of 0.3 mm sec^{-1} to 1.0 mm sec^{-1}. It will be improved to 0.03 to 0.05 mm sec^{-1}. The European Space Bureau plans to use laser interference to measure the distance variation between satellites. Its accuracy is primarily determined by the stability of the laser frequency marker. Satellite altimetry is a technique to directly measure the altitude of the satellite (limited to the altitude of a satellite above sea level). Its accuracy is of the order of several dozen centimeters. This method is primarily used in special research projects such as in the shape of the earth and its gravitational field.

III

As a satellite circles around the earth, it is perturbed by many physical parameters of the earth and its surrounding environments, such as the non-spherical pertrubation of the earth's gravitational field, damping due to the upper atmosphere, solar and lunar attraction, solid and ocean tides on earth, solar radiation pressure and geoalbedo pressure, polar shift and spin of the earth, and the mutual interaction between the satellite surface charge and the earth's magnetic field. In order to accurately study the

motion of a satellite, we must analyze the perturbation sources. As we review the history of satellite dynamics, the study of satellite motion is closely linked to the study of the earth and its environment. It will be difficult to obtain any progress without satellite observation and analysis of perturbation sources. Before the first satellite was launched in 1957, some knowledgeable scientists, such as Director Webber of the Smithsonian Observatory, predicted the importance of satellite tracking and satellite dynamics with regard to the study of the shape, gravitational field and upper atmosphere of the earth. Furthermore, he built a worldwide satellite photographic tracking network and prepared the world's first "standard earth" model.

Because of the uneven distribution of density and the irregularity in shape, the equipotential surface of the earth's gravitational field is not spherical. The satellite orbit change thus caused is called perturbation by earth configuration. Because most of the earth surface is the ocean, snow covered mountains, and desert, it is difficult to determine the earth configuration by conventional geodetic measurements (such as gravity and arc length). For example, it took several hundred years to obtain the conclusion that the earth is similar to a rotating ellipsoid. But the error of the compression of the earth is more than 1/300. The perturbation caused by the flatness of the earth will make the orbital plane of the satellite to rotate around the axis while maintaining the same dip angle relative to the equator. This effect is analogous to the motion of a top under gravity. The rotation of the orbital plane is very fast. An orbit near the equator will shift by about 8 degrees west and the polar orbit is decreased to zero. After the U.S. launched "Pioneer I" in early 1958, the rotation speed was found to be 0.7 percent smaller than the value calculated based on the flatness obtained by geodetic survey (1/297.1). Hence, the difference could be 2 degrees after 100 days. The satellite was located at 150 km east of the projected position at 50° north in latitude. Based on this data, it was derived that the equatorial radius is 1/298.3.

Several months after "Pioneer I" was launched, another major discovery was revealed. The distance between the perigee and the earth center is 7 km shorter in the northern hemisphere than the southern hemisphere. This indicated that in addition to the linear reduction of the perigee radius due to atmospheric damping, there is another sinusoidal oscillation whose period happens to coincide with that of the perigee motion. It demonstrated the asymmetry of the earth gravitational field. Based on this finding, we could conclude that the earth is not just compressed but pear (or orange) shaped. The stalk is at the north pole. The south pole area is indented while the north pole area is raised. A person standing at sea level at the north pole is 40 meters farther away from the equator than the one at the south pole.

The British discovered that the error along the direction of a satellite appeared to follow a sinusoidal pattern based on observation by a meridian instrument in 1961. The period was approximately half a day. The amplitude was several hundred meters. This could only be explained by the fact that the equator of the earth is also elliptical and the difference between the long axis and the short axis is approximately 300 meters.

As the accuracy of satellite observation continued to improve the shape of the earth was found to be more and more complex. The gravitational potential of the earth is usually expressed by the serial expansion of a spherical function. The first thousand terms will significantly affect the motion of the satellite. The progress made by the U.S. Navy in the study of the gravitational field of the earth by a navigation satellite gradually raised the accuracy of satellite orbit fixing and navigation. It is an outstanding example in which the study of satellite motion is closely linked to the analysis of perturbation sources. In the early 1960's, due to the error in the model of the earth gravitational field, the error in satellite orbit determination in a day or for the next day was a fraction of a nautical mile. Fortunately, the motion of the meridian instrument satellite itself provided a powerful tool in the study of the gravitational field. As the model of the gravitational field gets perfected, the accuracy continues to improve. Since 1977, after adopting a 20th order gravitational field model, the residual error in satellite tracking is decreased to approximately 6 meters.

The damping effect of high level atmosphere is another important factor influencing the motion of low orbit satellites. After satellites were launched, we discovered taht the thickness of the atmosphere is much thicker than we had in mind. Furthermore, it varies weekly, seasonly and semi-annually, especially vigorously with solar activites. This led to the failure in the prediction of the fall of earlier satellites. There is still a 10 percent error in calculating the atmospheric density in the upper atmosphere by the current model. Furthermore, due to the uncertainties of the effective surface area to mass ratio of the satellite and the atmospheric damping coefficient, the orbiting accuracy of medium orbit satellites cannot be improved. This effect is minimized by using a correction factor.

After the U.S. launched its weather satellite "Echo I" in 1960, it was discovered that its period and rate of change in period did not vary monotonically with time t. The change in the eccentricity of the orbit was found to have a long period and large amplitude. This led to the study of light pressure perturbation. Light pressure perturbation can be accurately calculated for satellites with a stable area to mass ratio by taking the earth shadow (umbra and penumbra) into careful consideration. The pressure on the satellite from the sunlight reflected by the earth--the earth shine pressure--is relatively small and can be neglected. However, it may become an important factor for geodynamic satellites whose accuracy requirement is extremely high. Because the albedo intensity varies widely, it is very difficult to establish an accurate model. In recent years, people discovered that the orbit radius of the laser geodetic satellite "Lageos" was decreasing by 1 mm per day from data analysis. This phenomenon could not be satisfactorily interpreted. Initially, it was attributed to the added resistance produced by the interaction of charged particles on the surface and the earth magnetic field. However, it was later found that the acceleration of the satellite was periodical. Therefore some people believe that the most probable cause of this oscillation is the asymmetric variation of the earth reflection light pressure. Because there is no agreement in this area, this is only considered as an experience.

In addition to the attractive effect of the sun and the moon on the satellite, they cause the elastic deformation of the earth, i.e., the solid tide and ocean tide which cause the gravitational force of the earth to vary periodically. The perturbation thus provided is called tidal perturbation. On the other hand, the solid tide also varies the coordinates of the observation station. This is one of the important problems in recent years. Calculation and analysis of satellite perturbation are being performed based on the tidal models provided by satellite survey and geophysics (such as the Wahr solid tide model and the Schwiderski ocean tide model). In addition, there are perturbations caused by meteor collision and the thrust of small rockets.

In summary, the laws governing the orbit of a satellite involve many complicated physical problems. The present theory in satellite dynamics is focused on the accuracy of perturbation factors. We believe that many other less effective perturbation factors are still to be discovered as work on satellite observation and large time span satellite orbit calculation continues. We know perturbation sources are yet to be further refined, which is also a significant area to be developed in satellite dynamics.

IV

From the above we know that the perturbation force on a satellite is extremely complex. There are attractive forces due to discrete point masses in traditional astronomical dynamics as well as attractive force from continuously distributed mass such as the earth, dissipation force due to atmospheric damping, intermittent force caused by light pressure and electromagnetic force exerted on charged satellites. In addition, there are some unknown forces. Therefore, the equation of motion of the satellite is extremely complex. People are still unable to find an exact solution. Only approximate solutions are available. There are basically three methods i.e., analytical method, numerical method and qualitative method, and a combination of them such as the semi-analytical and numerical method.

In the early stage (approximately 10 years) of satellite dynamics, methods to analyze satellite perturbation have been rapidly developed on the basis of classical celestial dynamics. If a satellite is only attracted by the gravitational force from the center of the earth, then the orbit of the satellite is an invariant ellipse. The perturbation force causes the elliptical orbit to change continuously, including long-term change, long periodical change and short periodical change. However, because the perturbation force is a small quantity relative to the gravitational force of the earth, the elliptical orbit of the satellite varies very gradually. Therefore, when we discuss the approximate analytical solution of the satellite motion, the orbit root or its equivalent complex conjugate variable is usually used to replace the rectangular variable to establish the Lagrange or Delaunay equations to obtain an approximate series solution by iteration through series expansion. For a conservative force field, a regular transformation such as Lee transformation is used to find the solution. In practice, people usually employ the mean root method which was developed in 1959 based on the method of average in the theory

of non-linear vibration. It involves the use of the mean root (eliminating long and short or just short periodical terms from the instantaneous oscillating element) to replace the oscillating root in order to improve the convergence of the series. In addition, some people used the intermediate orbit concept in celestial mechanics to replace the elliptical orbit with an intermediate orbit which is closer to the actual motion and whose solution is expressed in a closed form, such as the intermediate orbits introduced by Stern, Vinte and Arkshinov. They are rarely used in practice because the expression of the intermediate orbit is too complicated and cannot fully reflect the major term of non-spherical perturbation. It is also relatively complicated to further determine the perturbation term.

People established the earth configuration perturbation theory, atmospheric perturbation theory, light pressure perturbation theory and perturbation theory involving the sun, the moon and the tide based on the aforementioned analytical method to complete the theories in satellite motion. Furthermore, some encouraging results have been obtained in practice. For example, the Smithsonian Observatory established the Smithsonain standard earth model using the analytical method.

However, the analytical method encountered great difficulties because the accuracy of observation is rapidly rising, the study of statllite perturbation source becomes more profound, and the accuracy requirement for perturbation calculation is much higher. In the meantime, large scale high speed computers are also widely used. Hence, people are relying on numerical integration methods such as the Cowell method, Adams method and Runge-Kutta method, in high precision applications. In addition to orbit element, the rectangular coordinate is also directly used as variables. For example, major satellite conputation centers such as JPL, NASA/GSFC and DMA in the United States as well as CNES in France are using numerical methods to accurately calculate satellite perturbation. Therefore, the research on numerical integration is also rapidly advancing with more than a dozen frequently employed methods. A method to directly integrate a second order differential equation has been used to accomplish fast speed and high accuracy. Numerical methods can also help people to analyze satellite perturbation sources. For example, the long (several hundred day interval) and short (several days) orbits are used to simulate the tidal perturbation of a laser geodetic satellite. We can project that numerical methods will become more important in the future. Analytical methods, of course, will still have certain theoretical significance. They are still the fundamental knowledge to be grasped by workers in satellite dynamics and will remain to be one of the tools for residual error analysis. In low accuracy perturbation computations, they also have the advantage of fast speed.

Qualitative methods emphasize the study of satellite motion instead of specifically calculating the position of the satellite. For example, the stability of synchronous satellite motion and the non-translational critical angle in satellite motion often involve the qualitative and stability theory in differential equations.

The semi-analytical semi-numerical method is a compromise. For example, a numerical method can be used to find the mean root at any distance and an analytical method can be used to obtain first order short cycle terms. The second order short cycle terms, however, are obtained using Fourier series approximation. Thus, the advantages of simple formula and short computation time are both included with some accuracy.

In the above, we introduced the problem to solve the differential equation of motion of a satellite. In solving this problem, we must know the initial state of the satellite, such as the orbit element or coordinate and speed at t, i.e., the initial conditions of the differential equation. In the computation of the satellite orbit, people assume that the orbit is an unperturbed ellipse. The rough initial values of the orbit are determined from observation. These values are further refined based on observed date by taking perturbation into account in order to obtain the state of motion at any instance. This is the so-called problem of initial satellite orbit calculation and orbit improvement.

From celestial mechanics one knows that if the orbit of a heavenly body is an unperturbed ellipse then the orbit element can be calculated if the radial distance and the rate of change of radical distance at one instance or radical distances at two instances are known. The Gauss method provides a way to calculate the radical distance at two instances with observed direction values obtained at three instances. The LaPlace method offers a way to calculate radical distance and rate of radical distance variation. These two methods are also suited for multiple observation. Since satellites are launched, Gauss and LaPlace method have been improved. Furthermore, many new methods have been developed to solve problems in various types of satellite observation.

Improving the orbit of a satellite is the key to the accurate determination of the orbit, in which perturbation calculation is fundamental. Current advances in satellite observation allow people to capture a great deal of highly accurate data. The problem is to effectively and accurately process these data to improve the orbit and to estimate certain satellite dynamic, geophysical, geodetic and geodynamic parameters. Data processing method is the key to success in this work. This is determined by the applied nature of satellite dynamics which is another characteristic differing from celestial dynamics.

In celestial dynamics, people widely use the least square method created by Gauss in 1795 to calculate the orbit of a planet. It was a powerful tool before any statistical information such as observation vector and satellite state vector were available. However, we are facing the following new problems:

1. How measured statistical information, including the amplitude domain (covariance, statistical distribution type, etc.) and the frequency domain (frequency spectrum distribution, correlation characteristics, etc.) can be determined in order to utilize such information more effectively to obtain the best estimation of a quantity related to one state of

a satellite. How the "wild" values in the observation can be eliminated to smooth out filtered wave and compress the measured quantity.

2. How the orbit of a satellite or a spaceship can be determined in real time, including fast target identification and adaptability to fast perturbation variation, in order to improve the efficiency and accuracy of computation.

3. How the computation of large matrices frequently encountered in orbit determination and estimation of parameters (such as the 700 x 700 matrix in the simultaneous calculation of 20 orders of gravitational coefficients and the coordinates of 100 stations) can be performed in order to overcome difficulties.

4. How acceleration information not included in a model can be obtained to modify the perturbation model to improve the accuracy in orbit determination.

5. How residual error can be analyzed to pin point the sources of error and to discover new perturbation sources.

One can see that satellite data processing is a complex and involved problem. It needs new mathematical methods and other new scientific accomplishments. In addition to least square deviation estimations, many other methods, have been developed including a priori weighted method for unknown parameters, sequential adjustment or step-by-step least square estimation, sequential estimation algebra and least square allocation. Furthermore, "statistical orbit determination theory" was established on this basis. This is an example in the theoretical development of satellite data processing. Work in this area continues.

Finally, we have to mention that the framework of Newtonian mechanics can no longer satisfy the present need as the study of satellite motion becomes more profound. In recent years, a series of parametric post-Newtonian forumlas was developed based on generalized relatively. It allows us to conveniently compare various attractive force theories with the experimental result. The vast space is used as an experimental site to perform various tests with an accuracy never attainable before.

V

Based on the above discussion, satellite dynamics not only directly serve the development of satellite series but also can widely be used in the national economy, defense and scientific research.

1. Geodely from Space. The gravitational coefficient, the dynamic flatness index; the long equational radius, the gravitational field index of the earth and the coordinates of all the observation stations in the world can be measured by the motion of a satellite. It is the most important aspect in applied satellite dynamics in the past 20 years. We experienced the stages of performing fundamental research, obtaining preliminary accomplishments, making accomplishments more precise and exploring new

methods. People have already established various standard earth models such as SAO, GEM, WGS, NWL, GRIM, RAPP, and APL. The error is 3-5 meters using a model to calculate a satellite 1,000 km up in the sky. It is less than 1 meter for the "Lageos" satellite. Furthermore, a control network more advanced than the ground astronomical triangular network has already been established.

2. Geodynamics and Astrometry. The study of satellite motion can provide direct measurements for polar shift, variation of rotational speed, plate movement, and mass distribution of the earth.

3. Study of Upper Earth Atmosphere. Various upper earth atmosphere models established before 1972, including CIRA international reference atmosphere model, are primarily based on the atmospheric denstiy and its variation pattern calculated from satellite motion. In recent years, many new models were built based on instruments (such as mass spectrometer, accelerator, non-coherent scattering, etc.) installed on satellites. However, a model based on satellite drag data is more appropriate for orbit analysis. On the other hand, the study of the effect of solar activity on the upper atmosphere density and the short term variation of atmospheric density is still an important problem of considerable concern.

4. Generalized Relatively and Space Gravitation Experiment. People have already routinely correct the data observed by satellite based on generalized or special relatively. In recent years, many new ideas have emerged to employ satellites and space ships to conduct space gravitation experiments. Examples include the measurement of the Lense-Thirring effect with a drag free satellite, the measurement of relativistic precession effect by using a drag free satellite as a top, and the detection of gravitational wave by the deep space Doppler tracking technique on a space ship. People are looking forward to the breakthroughs brought about by the experiments with excitement.

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APPLIED SCIENCES

GEOLOGICAL REMOTE SENSING DEVELOPS RAPIDLY, FINDS BROAD APPLICATIONS

Beijing ZHONGGUO DIZHI [CHINA GEOLOGY] in Chinese No 10, 13 Oct 84 pp 23-26

[Article by Yang Guangqing [2799 0342 1987]: "The Development of Geological Remote Sensing in China"]

[Text] Geological remote sensing has developed rapidly in China in recent years. All departments in China have actively fostered it as a new technique with great potentiality. Up to the present, the Ministry of Coal Industry, the Ministry of Metallurgical Industry, the Ministry of Nuclear Industry, the Ministry of Water Conservancy and Power and the Ministry of Geology and Minerals have established centers for geological remote sensing one after another. Moreover, the Ministry of Railways, some industrial departments and the State Seismological Bureau have their geological remote organs. There are more than 1,600 professional scientists and technicians in geological remote sensing for the above-mentioned departments and even more scientists and technicians use remote sensing data in their professional work. The Chinese Academy of Sciences and research departments on the application on remote sensing at some universities and colleges also include it for geological application. Each year various units deal with up to 100 engineering and research topics in geological remote sensing. The scope of application continually expands and practical results improve day by day. In the spring of 1981 the Chinese Geological Society set up its special committee on geological remote sensing, which shows that geological circles in China have stressed this new discipline and promoted its growth. In 1981 the special committee convened the first national symposium on geological remote sensing, and in 1982 and 1983 its successively convened symposia on special topics of geological minteral exploration as well as hydrology, engineering and the environment. The number of papers presented to these symposia exceeded 300. The periodical YAOGAN DIZHI [GEOLOGICAL REMOTE SENSING] initiated by the special committee will soon be published. In order to promote the application of remote sensing, all departments have stressed strengthening the training of professionally qualified persons and geology departments of all geological academic institutions and integrated universities have set up courses in geological remote sensing and some have even set up geological remote sensing as a specialized field. Several groups of graduate students have been trained. Those who participated in specialized training and classes for advanced studies operated by various departments number 3,000. At the same time, attention has been given to strengthening technical cooperation and interchange with foreign countries. Apart from

participating in some symposia, going abroad for further studies and conducting joint research, the Ministry of Geology and the Japan Petroleum [Development] Corporation jointly explored the Ordos Basin while the Ministry of Petroleum Industry and the U.S. Geological Survey jointly explored the Qaidam Basin and each case included geological remote sensing projects. Satisfactory results were obtained from image processing and the use of helicopters to conduct field exploration to reporting on interpretation and results. Geological remote sensing has already become an effective force in China's geological work and is a positive and active factor in driving scientific and technical development in geology.

Scope and Results of Application

At the end of the 1970's some people in the world reckoned that geological remote sensing was undergoing a transitional stage of production application and experimental work. In the light of China's conditions, it has reached production application in certain realms or areas of application and is continually expanding; and in some realms it is still undergoing the stage of experimental work. The discussions below focus on the relatively matured areas of production application.

1. Geological cartography. This is the earliest and most effective area of the application of remote sensing. The revision of 1:1,000,000 regional geological reconnaissance maps widely uses Landsat multispectral scanning data which has corrected certain ommisions and errors on former geological maps and has improved the quality of maps and charts. It has played an even more tangible role in the work involving regions in the western mountains and plateaus where accessibility is a problem. The use of aerial photographs and satellite images is already an indispensible method for 1:200,000 regional geological reconnaissance and it can increase the efficiency of conventional methods many times, distincly lower the cost, greatly reduce the amount of field work and enable even more energy to be spent on studying key topics thereby increasing the quality of geological maps. In the light of a great deal of practice, the Ministry of Geology and Minerals has already drawn up and enforced among various regional geological reconnaissance teams on a trial basis the "Technical requirements for the application of remote sensing images for carrying out 1:200,000 regional geological reconnaissance." In the future, 1:500,000 regional geological reconnaissance will develop in China on a large scale and it is expected that by the end of this century 2,000,000 square kilomters will be completed in the nation including prospect zones, key economic areas and vicinities of key cities. The primary use of aerial remote sensing in this reconnaissance project has already been included in the work regulations as a necessary method. The drawing of relief maps and Quaternary geological maps of various regions has actively applied remote sensing and given play to its role.

2. Study of geological structures. This is one of the most effective areas in using remote sensing. The large quantities of lineament and circular images shown on images for remote sensing have become the effective measure to uncover the mysteries of regions and partial structures.

Various schools in China have competed in the use of remote sensing data in drawing national or greater regional logical structural maps. Even more studies are carried out by combining the search for mineral deposits, hydrology, engineering, seismic geology and other areas.

3. General survey of mineral deposits. A large amount of this begins with studying the geological conditions of mineralization, its volume, and mineral control which indirectly helps prospecting. For example, on the basis of spectral data of ground determination to select better optical and computer processing programs, the Nei Mongol Autonomous Region traced ore-bearing positions in the Langshan region, studied mineral control structures and combined aeromagnetic maps and chemical exploration data to put forward prospect regions and found multi-metallic vulcanized deposits through verification by drilling. The Ministry of Nuclear Industry conducted computer processing of satellite data of the Nei Mongol region and has successfully tackled the characteristics of fossil stream channels and playa lakes which in turn helped to locate sedimentary uranium deposits and achieve results. The Ministry of Metallurgical Industry has studied the image characteristics of the copper and iron deposits in the Lower Chang Jinag, the molybdenum deposits of Jinduicheng in Shaanxi, the tin deposits in Gejiu in Yunnan, the copper depostis of Dexing in Jiangxi and other noted mining areas as well as the medium-acidic intrusive rock which are closely related to mineralization. The Ministry of Coal Industry used remote sensing data to study 70,000 square kilometers of vast but sparsely populated and coal-rich regions on the west slope of the Da Hinggan Ling in the Northeast to study the fault zones ans structures which control coal fields, and combined geophysical data to delineate 18 coal-bearing basins. In the peat survey of Chao Hu Lake in Anhui and Roige in Sichuan, peat fields were delineated marked out on the basis of dark features shown on remote sensing images of exposed and shallow peat sections. This is an effective example of direct prospecting. Preliminary experience has been obtained in the study of hidden structures by using thermal infrared to scan and draw large-scale coal geological maps in the Taiyuan region of Shanxi. The Ministry of Petroleum Industry has obtained results in studying structures from remote sensing data on some gas-bearing regions and from circular images of structures that may be related to gas-bearing structures. It put forward 29 circular images of the Qaidam Basin in Qinghai almost half of which were linked to geophysical and drilling data. Moreover, by using remote sensing in the untraversed Yingxiong Ling region in the western part of the basin, the eastern extension of a Ganjigou [1626 7162 3297] structure was discovered thereby filling the gaps on geological maps. An industrual gas current has been unleashed in its vicinity.

4. Hydrology and water resource survey. Remote sensing techniques have become routine and effective measures in this type of survey. For several years they have supplemented hydrogeological data in 20 1:200,000 regional geological reconnaissance maps. Tangible results have been obtained in the hydrogeological and soil erosion survey of the loess plateau region in the west; the investigation of spring origins, groundwater overflow zones and hidden water-bearing faults in arid regions; the division of alluvial fans, fossil stream channels and fresh and salt water distribution regions in

eastern plain regions; and the combination with methods of geophysical exploration to prospect for water-bearing faults. The use of computer processing of satellite data in the Chengdu Plain in Sichuan has successfully delineated sections of rich and deficient groundwater and estimated their water content. In the hydrogeological survey in the arid continental basin of Qinghai, the use of satellite photographs and 1:60,000 aerial photographs has successfully drawn up 5 zones from piedmonts to saline lakes.

5. Engineering geology and calamity geological survey. Along with the development of state construction, the application of remote sensing is increasingly important in the selection of railway lines, site selection of nuclear power stations, large reservoirs, dams and other projects as well as in the survey and control of landslides, collapses, scattering and other undesirable geological phenomena. Considerable economic results have been obtained. The use of satellite data has given us a preliminary understanding of the general patterns of the occurrence of the landslide and collapse of the Baocheng Railroad. The study of the landslide on the Baotian Railroad with aerial remote sensing data has provided a basis for transforming this railway section. In the preliminary survey of the TMG tunnel the use of remote sensing to supplement and revise the understanding of the fault and intrusive rock wall in that region has clearly described the undesirable geological phenomenon thereby providing a basis for the selection of tunnel engineering programs. In the survey of the Ertan hydropower project on the Yalong Jiang in Sichuan, distribution maps were made from aerial photographs which included over 100 landslide areas. Experience has proved and shown that the accuracy of interpretation is above 85 percent. In March 1983, a large landslide at Sale Shan in Dongxiang, Gansu, caused great losses in lives and property. Remote sensing was swiftly used to survey the site which provided an understanding of the nature and causes of the landslide and of possibly dangerous sections.

6. Study of seismologic geology. Ours is a country with plenty of earthquakes so that seismologic predictions and forecast is an important task. Remote sensing is mainly used for studying and background of geological structures of strong earthquakes, the relationship of active tectonics with earthquakes and seisomologic divisions. It is also used to provide basic data for medium- and long-term seismologic forecast and the origins of earthquakes, study the geological background of areas where earthquakes had occurred and monitored areas where earthquakes may occur in the near future, and to make engineering stability evaluation of large engineering facilities.

The ZHONGGUO HUODONG GOUZAO DIANYING WEIXING YINGXIANG TUJI [Atlas of typical satellite images of active tectonics in China] has been compiled and published.

7. Environmental geology and comprehensive survey of cities. Urban construction (urbanology) is a key topic in economic construction. With its rich information, direct visibility and speed, aerial remote sensing can play a key role in studying the geological background of cities, atmospheric

and water pollution, land utilization, thermal leak and tourist geology. In order to improve economic results we can conduct comprehensive surveys at the same time with topographic mapping, agricultural and forrestal survey, soil survey and city buildings. China has already begun this kind of comprehensive survey in some large cities and preliminary results have been obtained. We can expect that remote sensing technology to become a basic measure in city planning and management. The use of aerial infrared scanning along the Dalian coast has successfully discovered freshwater springs, which is a special case in the use of the thermal infrared method.

Progress of Methods and Technology

China has developed and is developing some new sensors (including microwave segments), photoelectric and computer data processing systems and visual interpretation equipment, some of which have been put into actual use. Recently synthetic aperture side-looking radars have been imported and soon resource satellite receiving stations will be built. All this will promote the development of geological remote sensing. The progress of the technology which has been in constant use in recent years is as follows:

1. Increase in the types of remote sensing method, increasing refinement from small to large scale. In aerial photography which has the greatest use in volume, there is increased use of high-resolution and information-rich color and color-infrared photography. Particularly with the latter, there is more extensive use for the water content and cholorphyll content of cultures in geoscience. Good results have been obtained in the construction of three-dimensional tertiary systems by satellites and remote sensing at 10,000-meter high altitudes to low altitudes, both the crude and general as well as precise and refined are used in combination and to supplement each other. The application of aerial infrared scanning and multi-spectral scanning is gradually being extended.

2. Application of remote sensing of multiple periods. The application of satellite remote sensing data from different seasons has long been emphasized. Aerial photography has been developing in China on a large scale for 30 years. Most regions have second and third generation or even more aerial photographs. Studying the geophysical and geomorphologic dynamic changes by contrasting aerial photographs of different periods frequently provides us with important facts. The study of the general patterns of changes in the river course and silting in the Zhenjiang region of the Lower Chang Jiang has brought important results to the study of the development of the Huang He Delta and the traces of new activities of the paleo-landslide in the Sale Shan region of Dong Xiang.

3. Use of comprehensive methods. This is the only way to overcome the limitation of the unitary method of remote sensing. Numerous facts have proved that in mineral survey, comprehensive use of remote sensing technology with aerial geophysical exploration, gravitation and electrical data, good results in prospecting can be obtained in multi-metallic minerals particularly by combining with chemical exploration data. Combining aeromagnetism and gravitation in the study of tectogenesis and partial

structures, combining artificial seismological method in gas survey in the study of depth structures, combining gravitation and aeromagnetism in hydrological survey and water prospecting in the study of bedrock undulation as well as the use of electrical method to find water-bearing faults and aquifers have gradually become measures people readily adopt.

4. Use of computers to process and interpret digital image data has been gaining popularity since 1980. In the present symposium over 10 papers have included results of this application. In order to make possible for information retrieval, statistical classification and automatic recognition, other than using matured methods and prcedures, software is being developed and some effective procedures have been compiled. Some scholars insist on the necessity of coordinated implementation of computer processing and visual interpretation. Preliminary visual interpretation will help in the correct selection of processing methods and parameters and will avoid arbitrary use of large numbers of processing procedures which waste machine time. Repeated visual interpretation of the results of processing will help to enrich the substance of interpretation and avoid certain pseudomorphs which may be created by pure reliance on mathematical operations.

5. Multiple utilization. Remote sensing is basically synthetic information. Only by comprehensively using them in multiple areas can they bring greater economic results. The use of aerial remote sensing to draw relief maps and geological maps at the same time has long been an effective method used by the Ministry of Coal Industry. Recently the Ministry of Metallurgical Industry has also done experiments and proved that it is possible to reduce the work period from 2 or 3 years to 1 year, reduce the amount of field work by two-thirds and save outlay by two-thirds to one-half. Comprehensive survey of cities discussed above is also recommendable, since one session of remote sensing can benefit many sides and draw several to more than 10 types of serial maps.

Guiding Principles and Orientation

China is a developing country. It lags behind industrially-developed countries in its economy, science and technology, and its geological remote sensing developed late. Our guiding principle is that in the short run we should first learn the effective methods and techniques from various countries, selectively import and transplant those that suit our national conditions and needs and make the necessary transformation to enable them to play their role in applying them in China and in speeding up China's modernization. We should develop and improve them in the course of applying them and strive to make our contribution.

1. Develop what is useful and avoid what is not, strive for practical results. Some geological departments frequently put prospecting in a prominent place but what remote sensing directly indicate is information of the earth surface and it is hard to obtain substantial results in direct prospecting. We should therefore stress the greater role it can play in indirect prospecting and other areas mentioned above. As departments of practical application, in large-scale remote sensing projects we frequently

treat engineering areas of application or those that we are confident to yield practical results as the primarily and research topics as secondary, and we use the numerous results obtained from engineering application to support research and development.

2. Closely combine with the needs of state construction, strive to reach the forefront of conventional work on the ground. Excluding basic geological surveys, there are 297 key projects in China. These include numerous resource and environmental surveys as well as preliminary projects and we must build several key economic regions and prepare for the development of the great northwest. Remote sensing must be actively involved in all this and we must give play to its favorable conditions of speed and low cost and strive to reach the forefront.

3. Extend the scope of application, actively penetrate into the peripheral disciplines. Apart form the various areas of geoscience, we must extend its application to the broad environmental sciences dealing with agriculture and forestry, cities and oceans. This is an important direction in improving social and economic results which will in turn promote the growth of the discipline of geological remote sensing.

4. Combined use of specialists and non-specialists, improve and popularize this combination. Apart from relying on special organs in geological remote sensing as well as scientists and technicians as the backbone, we must encourage scientists and technicians in all specialties to use remote sensing technology and data in their actual work.

5. On the basis of existing conditions, suit measures to the time and local conditions, work while we develop and at the same time pay attention to the new situation. For example, the setting up of satellite receiving stations and the application of side-looking radars may change certain of our work methods and procedures. Moreover, in view of the rapid development of microcomputer technology it is possible that we may use the much cheaper microcomputers to do digital image processing which originally had to be done by mini-computeres thereby popularizing it even faster.

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APPLIED SCIENCES

NUCLEAR POWER IN CHINA

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[Article by Gerard Gourievidis, nuclear adviser to the French Embassy in China]

[Text] **After outlining China's situation with** respect to its energy supply and pointing out the principal problems confronting the country in this domain, the author discusses the nuclear energy option adopted by the authorities. He retraces the stages in the development of the Chinese nuclear program, its accomplishments, its orientations and the projects in progress. He then describes the organization of China's nuclear research effort and of its nuclear industries, the situation with respect to its fuel cycle, and the country's uranium resources. Lastly, he discusses the international policy the Chinese authorities have adopted with respect to nuclear cooperation, and the agreements they have signed with different countries, particularly with France.

I. The Place of Nuclear Power in the Energy Outlook

Objectives

At the 12th National Congress of the CCP [Chinese Communist Party], held in Beijing 8-11 September 1982, Mr Hu Yaobang--at that time, president of the Central Committee of the CCP and presently the party's secretary general--defined the economic objectives of the PRC [People's Republic of China] through the end of this century:

A quadrupling of the annual total of industrial and agricultural production between 1980 and the year 2000.

The end of the century would thus see a doubling of energy consumption with respect to the start of the 1980's, to a level of 1.3 to 1.5 tec [tons of coal equivalent], with production of electricity attaining a level of 1,200 TWh [terawatt-hours].

Despite a remarkable growth since 1949, energy remains one of the bottlenecks being encountered by the country in its economic development, and this notwithstanding its wealth of energy resources.

Problems

--Coal resources--the second largest worldwide--were estimated to be 660 billion tons as of 1983, concentrated mainly in Northern China (60 percent of all reserves) where the [province of] Shanxi alone has one-third of them.

Production in 1983 (see Table 1) totaled 700 million tons and will very likely exceed 800 million tons in 1990. Despite sizable outlays to modernize transport facilities, the problem of distribution of such a quantity of coal remains insurmountable. The fact is that around 40 percent of rail traffic and 50 percent of waterways traffic are dedicated exclusively to the "displacement" of coal, considering that less than 1 percent of the country's coal reserves are found in the immediate vicinities of Shanghai and the four provinces that shelter over 20 percent of the Chinese population and around 28 percent of its industry.

--Its potential oil reserves could be around 50 billion tons over the 9.6 million km^2 covered by the PRC, more than 4.2 km^2 of which consist of sedimentary layers, to which must be added close to 1 million km^2 of continental shelf.

Oil production rose sharply beginning in 1960, exceeding 100 million tons by 1978. With 106 million tons today, China ranks as the world's sixth largest producer.

Inasmuch as the oil deposits now being exploited have for the most part reached a certain maturity, it is unlikely that their present level of production can be maintained in the future. Moreover, although its offshore areas and the province of Xinjiang--highly promising--are being systematically explored with foreign assistance, the exploitation of new deposits is, in the best of cases, unforeseeable before the end of the coming 10-year period. This means, therefore, that over the short and medium terms, China risks becoming an importer rather than an exporter of oil, thus losing in the process a valuable source of badly-needed foreign exchange.

--Concurrently, gas production has attained an average of 14 billion m^3 over the past 3 years, putting China in 13th place worldwide.

--Of China's estimated 680 GW [gigawatts] of hydroelectric resources, 70 percent of which lie in its Southwest and 11 percent in its Northwest, only 378 GW are considered exploitable, and even so, at high cost and a long delay before reaching operability. Average annual production presently runs around 85 TWh, representing 8 percent of total energy consumption.

Of a total production of 349.3 TWh of electrical energy in 1983, 25 percent was provided by hydroelectric power; coal and oil accounted for the rest.

This seeming well-being masks many problems in the offing. Whereas the 6th 5-year plan (1980-1985) called for an average annual growth rate of 4 to 5 percent, Chinese industrial production actually rose at an annual rate of 7.3 percent between 1979 and 1982, indeed 10.2 percent from 1983 on. Unfortunately, heavy industry grew at a faster rate than light industry, which is contrary to the objectives assigned by the plan, thus entailing a great deal of waste owing mainly to the paucity of energy. The putting in place of an austerity program to rationalize the use of energy, and the modernization of its transport facilities, together, will still not suffice to overcome this country's energy crisis.

It is virtually a foregone certainty, as of now, that the more the economy grows, encouraged by the Government, furthermore, so as to attain its "Year 2000" objective, the greater will be the shortage of energy by the end of the current 10-year period.

A quadrupling of the gross annual industrial and agricultural production between 1980 and the year 2000, and concurrently doubling the production of coal and quadrupling that of electricity, while considerably improving energy yields--all so as to provide for a doubling of energy consumption and the availability of necessary surpluses for export--is an ambitious goal.

The Chinese authorities are aware of this and, with their past and the evolution of other foreign countries constantly in mind, are tireless in their efforts to prove the possibility of attaining the goal that has been set.

One Solution

One of the natural corollaries flowing from this situation is the very special attention being given by the Chinese Government to nuclear electric power in its medium- and long-term energy policy.

China was among the first countries to recognize that nuclear energy represents a dual--strategic and technological--advantage, and it was arguments in this respect that provided the impetus towards a research program that is modest, to be sure, but nevertheless substantial. Among the arguments advanced, we cite the following:

a) The use of nuclear energy in industrial and densely populated regions would facilitate the overcoming of the bottleneck stemming from the coal transport problem;

b) As a corollary to point a), the production of electricity would be independent of coal production and, therefore, of the location of the mines;

c) The introduction of nuclear energy would reduce the pollution caused by thermoelectric plants;

d) The cost per nuclear kWh [kilowatt-hr] would be less than that per thermal kWh, according to recent estimates;

e) The introduction of nuclear energy, as in the case of China's two big neighbors--India and the USSR--will necessarily have a double impact on its industry, in that its survival will depend on its growth.

The introduction of nuclear energy, which rests essentially on an existent industry, an outgrowth of the military program, will, however, be slow, owing to the economic situation, the insufficiency of the industrial infrastructure and the time required for training qualified personnel in sufficient numbers.

On the other hand, China possesses large reserves of uranium and has built --here again for its military requirements--a complete fuel-cycle infrastructure. The latter must nevertheless be considerably enlarged before it can support a vast nuclear energy program.

Thus, the gradual installation of a resolutely modern economy--more credible than the shibboleths launched in past years--will permit China, in spite of the difficulties it will encounter, to make the best possible use of the means already in its possession, provided it makes adequate use, initially and in the interest of modernizing its industry, of foreign technologies.

And thus it is that the Chinese Government decided to launch a nuclear-energy program. It decided to build two nuclear power stations in the course of the 6th Plan (1980-1985): One, a 300-MW(E) [megawatt electric] station at Qinshan, and the other a 2 X 900-MW(E) station in [the province of] Guangdong (Daya Bay).

The 7th Plan (1985-1990) would include the construction of two additional stations (of the 900-MW(E) type): One in the East (Huadong), and the other in the Northeast (Liaoning).

A further project is under study at the Southwestern Engineering Center (Ministry of Nuclear Industry) to install two heat reactors near Shanghai for the purpose of providing steam (800 tons/hr) to the Jinshan petrochemical complex. The objective here, as elsewhere, is to economize on coal and oil.

Although its short-term nuclear program is based on PWR [pressurized water reactor]-type plants, China intends, nevertheless, as Mr Jiang Shengjie indicated at the 2nd congress of the Chinese Nuclear Society, to build a breeder reactor, so as to be in a position within the intermediate term, to pave the way towards the commercial development of such plants.

In the end, however, the penetration of nuclear-fueled electric power into the Chinese energy program, as is the case elsewhere, will be limited by the size of the networks, which, seven in number, are not interconnected. The largest is that of the East with around 16,500 MW(E) (Table 3).

Furthermore, the Government has expressed the desire that between now and the year 2000, 10 GW(E) [gigawatts electric] be introduced into the network, a figure that appears, a priori, somewhat optimistic.

II. Nuclear-Fueled Energy Program

Brief Historical Background

The history of Chinese nuclear energy is closely linked to that of the Chinese People's Republic itself. In 1949, the Central Council of the People's Government (presently the Council of State) created the Academy of Sciences and 22 research institutes attached to it. It was not until the signing of the nuclear cooperation agreement with the USSR in 1955, however, that the nuclear program in China, a militarily-oriented program, actually got under way. A Nuclear Energy Research Service was specifically created in 1957 within the Institute of Physics, a service that underwent progressive change to eventually become the Atomic Energy Institute of Beijing, under the Academy of Sciences.

In or around that same period, China also signed a scientific and technical cooperation agreement with respect to defense matters with the USSR, giving China access to information relative to nuclear energy for military uses.

In 1958, the year in which the State Commission for Sciences and Techniques was created, China put into service, with the support of the USSR, its first experimental reactor--a 10-MW, heavy-water, slightly-enriched-uranium (2.5 percent) reactor, whose power output was increased to 15 MW after major modifications made to it in 1979-1980.

After breaking off relations with the USSR in 1959, China found itself on its own in pursuit of the development of its nuclear program, and appears to have succeeded, over a period of 4 years and by its own means, in putting into service five reactors, including the 3.5-MW swimming-pool reactor, as well as a gaseous-diffusion uranium-enrichment plant in the region of Lanzhou, provice of Gansu.

China exploded its first A-bomb in 1964, and its H-bomb 2 and 1/2 years later.

These purely militarily-based activities, however, probably had little or no stimulating effect whatever on the development of a civil nuclear industry. Actually, the experience acquired in the building and operation of plutonium reactors cannot be directly transposed to the sophisticated domain of power reactors.

Thus, this country--which had already laid the technical groundwork for a fuel-cycle and nuclear-reactors development program as far back as the mid-1960's--showed no incremental interest in the civil nuclear domain until the early 1970's, when it eliminated certain barriers to research and transferred some 2,000 to 4,000 engineers and higher-echelon management personnel from the military to the civil sector.

The newly instituted activities, such as studies on:

--Nuclear electric power generating systems,

--Controlled fusion,

--Vitrification and solidification of highly- and moderately-radioactive wastes,

--Breeder reactors, etc,

all underwent, in varying degrees, the backlash of the Cultural Revolution, and it was not until the mid-1970's that the clear intent finally emerged to use nuclear energy for peaceful purposes both in the domain of electric power reactors and in that of the manufacture and use of radioisotopes.

Nuclear Power Plants

China has opted for the PWR system, this being the most widely used throughout the world and that in which competition among the suppliers is the most intensive.

Two distinct approaches to the introduction of nuclear energy in China are in evidence:

--One, favored by the Ministry of Nuclear Industry, advocates in particular a 300-MW(E) model of PWR of domestic design and construction;

--The other, advocated by the Ministry of Water Resources and Electric Power, calls for initially importing 900-MW(E) PWR plants using foreign technology.

300-MW(E) Plants

The Ministry of Nuclear Industry, which until 1982 was known as the 2nd Ministry of Machine Industry, was given the task, during the 1970's, of comparing the different systems and recommending a choice. These studies, carried out with the help of institutes working on different types of reactors, dragged on at some length. However, the 300-MW(E) PWR project advocated by Shanghai's Institute 728 (728 is derived from "8 February 1970," the date on which the project was approved by Zhou En-lai) took a clear lead over all the others, and particularly over a 125-MW(E) heavy-water plant project. This model had been recommended mainly because of technical and industrial considerations (its equipment and components being of a size that would permit their fabrication in China, if not for the initial phase, at least for those that would follow), and considerations relative to the size of the country's existing electrical power networks.

It should be noted that Chinese industry manufactures, rather currently at present, power plants--thermal--of this capacity in 18 to 20 months. The construction, with success, of the 125-MW HFIR [high-flux isotope reactor]

whose criticality was announced in January 1981 is also to be credited to its balance of assets. If one adds to these accomplishments the nuclear-powered submarines China probably possessess at present, it would be a mistake to underestimate the Chinese industrial potential in this domain.

The Chinese electrical power networks--seven in number (Table 3)--are not interconnected. The largest is that of the East, with around 16,500 MW(E).

As viewed by the Ministry of Nuclear Industry itself, the aim of the 300-MW(E) "experimental" plant would be to gain, by building it, experience in the various domains of engineering, manufacture of components, quality control, testing, putting in service, and operation. The training of management and operating personnel would go forward concurrently.

The uncertainty, however, lies in the future of this type of plant, the project for which is being seriously put to question by the other technical ministries concerned, which are entirely sold on the 900-MW(E) type to the exclusion of all others.

There can be no doubt, however, that the experience gained by way of the 300-MW(E) plant will enable China to advance in the direction of power reactors without having to depend on agreements signed with foreigners--agreements that can, in the final analysis, be denounced at any time by either party, which is not a very probable outcome but which has occurred in the past, with the USSR in particular.

Site

After comparing various placements, a site was selected on the seashore about 120 km south of Shanghai, at a place called Qinshan, in the province of Zhejiang.

The population there is sparse, seismic conditions are favorable, and there is enough space for the installation of two 300-MW(E)--and even 900-MW(E)--sections.

Site work has been started, with the putting in service of a first section targeted, in theory, for 1989.

Design

Institute 728's 300-MW(E) design is a very conventional 2-loop configuration (Fig 1). Nevertheless, a part of the project was awarded to a foreign firm for reasons of know-how.

Its zeal, enthusiasm and will to master the technology on its own notwithstanding, the Institute 728 team responsible for carrying out this project is sufficiently knowledgeable to realize the difficulties and problems in store for it. Thus, for the first section at least, Chinese industry, not in a position to manufacture certain components within the required

timeframe, such as the pumps, the reactor vessel, the core instrumentation, and possibly other items of equipment, is planning to place orders abroad for these items.

The Ministry of Nuclear Industry is doubling in brass as the industrial architect and the prime contractor, and is preparing the safety specifications, which will then be analyzed by the National Bureau of Safety (as it is temporarily being called) created recently within the State Commission for Sciences and Techniques.

The major components are, for the most part, to be manufactured in Ministry of Machine Industry plants, based on specifications to be provided by the Ministry of Nuclear Industry.

The power plant is to be operated either by the Qinshan Nuclear Power Corporation, an emanation of the Ministry of Nuclear Industry and very recently created, or by the Ministry of Water Resources and Electric Power. Neither of these possible outcomes can be considered sacrosanct at this time.

The Conventional Segment

The engineering and design of the conventional equipment and operations section have been assigned to the Electrical Energy Institute of Eastern China; the Shanghai Turbines Plant, under the Ministry of Machine Industry, will manufacture the turbine. This plant is associated with Westinghouse under a license agreement covering the manufacture of 300-MW(E) and 600-MW(E) turbines for use in thermal power plants.

According to the Ministry of Machine Industry, however, the 300-MW(E) turbine is to be manufactured using Westinghouse technology derived from the 600-MW(E) plant.

900-MW(E) Plants

While it is true that through the 300-MW(E) program China will be able to master, by its own means, the technology of nuclear plants of this type--through enhancement of its industrial capacity and training of personnel in sufficient numbers and to adequate levels of competency--it is also true that one of the solutions to its short-term energy needs must be based rather on the use of 900-MW(E) units. And despite the miracles to which this country seems to have the secret key, the building of these units by Chinese industry alone is out of the question before 1995.

It being manifestly clear that the authorities, particularly those of the Ministry of Water Resources and Electric Power and of the Ministry of Machine Industry, have no intention whatever of patiently awaiting the coming about of this development, the upshot has been that, to carry out its program and speed up construction of the plants, China has decided to bring in foreign technology and equipment.

First of all, and after a plethora of vicissitudes, the Council of State confirmed in November 1982 the inclusion of the two 900 MW(E) sections for Daya Bay in the 6th (1980-1985) 5-year plan, and, in April 1984, its intent to include in the 7th Plan four 900-MW(E) sections, two of which were to be installed at Sunan, near Shanghai, in the province of Jiangsu, and the other two in the Northeast of the country, very likely in the province of Liaoning.

Then, drawing on the experience gained through numerous negotiations with foreign entities, and particularly France since 1978, China very ably prepared a 2-phase equipment- and technology-import program.

Initially, and as regards the Daya Bay power station--the only project with serious chances of being completed within the short term--Guangdong Province planned to form jointly with Hong Kong a mixed company, which would be the future client of the station.

Hong Kong's commitment to buy a part of the electric power produced by the station provided, in fact, an elegant solution to the thorny problem of financing.

Thus, and considering the very particular nature of this operation, it became inevitable that Great Britain would supply some of the equipment, including specifically the conventional segment, in spite of the problems posed by this choice. The Chinese authorities, moreover, did not categorically make known their decision on this point until November 1982, thereby putting an end to the hopes French industry had of furnishing the turbo-alternators.

As for the nuclear unit, France, which had for several years been maintaining close relations with the Chinese in this domain, was asked to submit a bid on the furnishing of the two 900-MW(E) units for Daya Bay.

Subsequently, and realizing that a vast technology transfer program could not reasonably be expected to result from the construction of two nuclear units alone, the Chinese Government decided to place an order with France, "subject to certain conditions," for four nuclear units and for all the related technology that would enable China to master alone, or almost alone, the construction of the fifth unit. A memorandum to this effect was signed between the two governments during President Mitterrand's visit to China in May 1983.

Thus, in addition to the Daya Bay station, the construction of the Huadong station also received approval by the Council of State.

It goes without saying that the Chinese nuclear power program awakened a very keen interest on the part of other countries, such as the United States, the FRG [Federal Republic of Germany] and Japan, to mention only the principal ones, with which China, of course, did not forgo the opportunity to consult.

In any case, although the attitude adopted by the Chinese authorities insofar as dealing with this important question is concerned continues in keeping with the spirit of the Franco-Chinese memorandum signed in 1983, the long-term success of the operation is nevertheless, also and above all, dependent on actual price levels charged, the financing terms offered, and the terms and conditions set up relative to the technology transfer that is to enable China, within the intermediate term, to manufacture on its own the equipment needed for nuclear power generating stations.

Obviously sure of the scenario they have adopted, the Chinese authorities have announced that they estimate a period of 6 years to be sufficient for the construction of the first section of the Daya Bay power station, on which on-the-site work is to begin 1 June 1984. The Chinese authorities expect criticality of the first section by the end of 1990, and that of the second section 1 year later.

III. Research and Industry

Research

The State Commission for Sciences and Techniques is the governmental body responsible for the planning and coordination of research, and for scientific and technical cooperation with foreign entities.

Created in 1958, it is placed directly under the control of the State Council. It is an offspring of the State Technology Commission and the Scientific Planning Commission. It was eliminated during the Cultural Revolution and re-established in October 1977. Since 1978, the Commission has been headed by Mr Fang Yi, assisted by two vice-chairmen.

Its authority extends over all administrative bodies and organizations concerned with the carrying out of the national research program: Autonomous academies, specialized academies and institutes funded by the technical ministries, including the Defense Ministry, and state bureaus with science--oriented functions.

The authority of the State Commission, though institutionally well established, does not, for all that, preclude a praxis of close-knit consultations between it and its major scientific agencies on the working out of research orientations. The control exercised by the Commission is more or less determinative in these sectors.

For the basic sciences, in which work is essentially the province of the Academy of Sciences, the links between Commission and Academy are perpetual and close-knit (their offices are located in the same building). Both institutions were initially headed by the same man (Mr Fang Yi) until the major reform of the Academy of Sciences which took place in 1982.

On the other hand, with respect to military sciences and techniques, the Defense Ministry appears to enjoy a certain autonomy: It has its own

scientific and technical commission, and retains authority with respect to research and development on missiles, nuclear arms and advanced weaponry.

Certain scientific activities are also assigned to state bodies operating directly under the State Council; this is the case with respect to oceanography, geodesy and cartography, seismology, etc, and, as of recently, nuclear safety.

The prevailing impression is that of a certain flexibility, which is being manifested in the form of encouragement towards the decentralization of decisions and a seeking of quick responses geared to the new problems. Beyond the relative liberalism that is marking the post-Cultural Revolution period, this pragmatic attitude is in keeping also with the concern of the Government leadership for bringing to the fore, through the workings of open scientific competition, individuals and teams capable of raising themselves to international standing.

Implementation of the scientific policy laid down by the State Commission for Sciences and Techniques is the responsibility of the bodies and intermediary administrations exercising authority over the departments, institutes and research laboratories funded by them wherein research programs are being carried out. With respect to the nuclear sector, this responsibility lies essentially with the Academy of Sciences and the Ministry of Nuclear Industry; and, though to a much lesser extent, with the Ministry of Education in respect to certain universities.

However, in the carrying out its mission and its scientific policy, the State Commission runs into the insurmountable handicap of being a body without a budget and--consequently--without a means of intervention in respect to the technical ministries and research entities, whose own programs are being developed with a legitimate desire for independence.

The conflicts that unfailingly result are not such as to favor the technological development being sought, or rapprochement among the researchers themselves. Government leaders are aware of this problem, and measures are being awaited that will bring the results of research to productive fruition and capitalize on the formidable asset embodied in the tens of thousands of Chinese researchers who are returning from abroad.

The role of the Academy of Sciences of China in the structuring of a scientific policy and in the defining of major priorities was preeminent between 1949 and 1956, a period in which the Academy was, in respect to these questions, the direct interlocutor of the State Council. However, the growing importance of the applied research functions assigned to the centers funded by the technical ministries, and the creation of the State Commission for Sciences and Techniques, have somewhat stifled this role. Nevertheless, the Academy of Sciences remains today the prestigious overseer of Chinese scientific research.

The number of Academy of Sciences institutes has varied considerably, going from 16 in 1949 to 119 today. The vagueness of the terminology used to

designate the different categories of researchers contributes little if anything to the clarity of available information. Thus, the Academy accounts for 35,000 "researchers" who share a budget (0.8 percent of the GDP [gross domestic product]) broken out as follows:

--Basic research	15.4	percent
--Applied research	49.6	"
--Development	31.5	"
--Other	3.5	" .

In "nuclear research," the Academy of Sciences relies on its institutes of physics, of high-energy physics, and of nuclear research in Beijing, Shanghai and Lanzhou, and on "its" University of Hefei where a synchrotron radiation installation (800 MeV) is being built, which should be completed in 1987 or 1988.

Institutes and Other Establishments Being Directly Funded by Technical Ministries: Several ministries, because of their technical functions, have responsibilities in applied research and have research establishments directly subordinate to them. Thus, the Ministry of Nuclear Industry has the Beijing Nuclear Research Center (which it shares with the Academy of Sciences) and the Southwest Nuclear Engineering Center, in Sichuan, as well as institutes such as the Beijing Nuclear Engineering Institute, Shanghai's Institute 728, and even the Uranium Geology Institute, etc.

It is not easy to evaluate the number of researchers working in scientific establishments directly funded by the technical ministries: One unofficial source puts the number of researchers and technicians in the Ministry of Nuclear Industry at 10,000.

The Ministry of Machine Industry and the Ministry of Water Resources and Electric Power also have their own institutes, some of which are in the nuclear sphere: The Shanghai Energy Research and Development Institute, pertaining to the Ministry of Machine Industry, and the East China Electrical Energy Institute and the "Suzhou Center," both the latter being under control of the Ministry of Water Resources and Electric Power.

The University...: Mention must be made of the Ministry of Education on which the universities and other institutes of higher learning depend.

Chinese university research exhibits its own characteristics: It does not constitute one of the essential facets of the activity of the personnel. Consequently, its level is, generally speaking, lower than that of other-than-university research, particularly that conducted by the establishments of the technical ministries. This tendency, however, could, in the case of some of the prestigious universities (Qinghua in Beijing, and Jiaotong in Shanghai), be reversed in favor of a solution combining university teaching and high-level research, as practiced in the West, and as is being advocated, as a matter of fact, by the thousands of Chinese university-level returnees from abroad.

Industrial Phase-In

While the State Planning Commission is responsible for the planning and integration of the major projects in the country's development program, their management is the responsibility of the State Economic Commission. The Ministry of Nuclear Industry, which has jurisdiction over the nuclear sector, is responsible for its development, in liaison with other technical ministries, particularly the Ministry of Machine Industry, that of Water Resources and Electric Power, and that of Electronics Industry.

Relations among the various ministries--at times complementary, and at times competitive--are still somewhat ambiguous and are constantly evolving in step with the evolution of the nuclear electric power program.

It is interesting to note in this regard that, contrary to the 300-MW(E) program, the 900-MW(E) program involves a sizable technology transfer operation. Because of the considerable difficulties introduced by such a transfer, probably the largest ever contemplated in the world to date, the Chinese Government has decided that it will be carried out by way of progressive participation of its industry in the manufacture of the items of equipment that will go into successive nuclear units. What this amounts to is--more than a mere technology transfer--a coproduction operation, in which the design studies and fabrication of items of equipment are to be carried out strictly on a joint basis.

This new operation, inspired, it would seem, by recent experiences--certainly not very comparable ones--with foreign entities, will require close cooperation among the technical ministries that fund the institutes, research centers and other production plant entities distributed throughout the four corners of the country.

The coordination of this vast and ambitious coproduction program has been assigned to the State Economic Commission, for reasons of competency and impartiality. This Commission already bears, in addition, the heavy responsibility for putting in place the Chinese nuclear electric power program, under the aegis, it is true, of Vice Prime Minister Li Peng.

A working group directly under the State Economic Commission has recently been created to negotiate with foreign enterprises on the phasing in of this operation. This working group includes--besides the representative of the Ministry of Machine Industry, who heads it--representatives of the Ministries of Nuclear Industry and Water Resources and Electric Power.

It is too early yet to judge the results of this new industrial policy and the effectiveness of an organization that will not be in a position to show what it is fully capable of until it has defined, in full detail, the different hurdles to be surmounted.

Among these, a detailed knowledge of China's industrial installations and of its "research" institutes appears to be one of the foremost concerns of the teams charged with defining, more or less, the siting program.

As a matter of fact, the initial exchanges of views and preliminary decisions on principle with respect to the undertaking having now been disposed of, what lies ahead is the need to determine, with a cold, technocratic realism, the portions of the design studies and manufacturing operations that are to be realized abroad and in China, the terms, conditions and procedures for integrating the Chinese teams into the foreign teams, and the means and investments to be committed to adapt certain establishments to the manufacture of nuclear components.

As regards the latter point, certain observations are in order, on which the very numerous foreign, and particularly French, technical and industrial missions that have visited China over the past 2 years are in general agreement: Once the initial impression of decrepitude that certain industrial installations can give has been overcome, one discovers organizations headed by highly capable men, backed by generally enthusiastic teams with an insatiable curiosity as regards foreign accomplishments and in which remarkable individualities are frequently discernible. Industrial equipment can vary considerably as to quality within any one establishment. The general impression in this regard is one of a certain backwardness, with, however, some notable exceptions. Light, conventional equipment is, generally speaking, of local manufacture: The advent of modern equipment manufactured in China is visibly on the increase. Frequently, the heavy equipment seen is a legacy from the era of cooperation with the USSR and was already obsolete at the time of its installation. Be that as it may, modern equipment, acquired principally in Japan, the United States and the FRG, is becoming more and more abundant. In many sectors, one currently discovers equipment of Chinese design, the performance of which is fully comparable to that of state-of-the-art realizations worldwide. This is the case especially with regard to instrumentation.

A major lag, however, must unfortunately be entered into the balance sheet: The scarcity and weakness of data processing equipment, computers, terminals, plotting tables, scientific peripherals. This situation is not owing to any shortcoming whatever as regards Chinese data-processing theoreticians, but rather to the industrial technological data-processing lag. The considerable outlay being put by the Government into the purchasing of modern equipment, involving a concurrent major technology transfer, should be such as to gradually bridge this temporary lag.

In short, in spite of its deficiencies of the moment, and notwithstanding the backwardness of the equipment in some of its plants, it appears certain that the Chinese technical and industrial community is potentially capable of meeting the challenge of building alone, or almost alone, the fifth nuclear section. It will still, however, have to be provided with the means, and these include, in particular, the necessary technology transfer, the incontrovertible fact being that design, fabrication and operation are linked to each other and interactively feed on each other.

IV. Fuel Cycle

China possesses large reserves of fissionable materials and has installed, initially for its military needs, a complete fuel-cycle infrastructure, under authority of the Ministry of Nuclear Industry.

Several bureaus operating under this ministry have responsibilities in the fuel cycle and thus have at their disposal specialized institutes.

The Uranium Geology Bureau, specifically charged with heading prospection and exploration, operates the internationally esteemed Institute of Uranium Geology. The fact remains that its former director, Mr Chen Zhaobo, promoted in March 1984 to vice minister, is the author of an original study on the relationships between the origin of granitoid and volcanic uranium deposits and the theory of plate tectonics. As regards the geological teams distributed over the Chinese territory, the programming of their activities is controlled by the provincial bureaus, on a decentralized basis.

The Bureau of Uranium Mines Exploration and Hydrometallurgy, whose functions are positioned upstream of the above-mentioned Bureau, heads all mine exploitation activities to and including the manufacture of the yellow cake. The Uranium Hydrometallurgy Institute operates under this Bureau.

And lastly, the Uranium Fuel Bureau is responsible for the enrichment, the manufacture and the reprocessing of fuels.

The largest known deposits are of the veinstone type associated principally with granitoid and volcanic rocks, and less frequently of the sandstone type. In addition, uranium can be found in conjunction with lignites, phosphates, and even in some cases with manganese, iron and mercury.

Despite the fact that information in this domain is quite rare, the principal deposits are nevertheless known and are found:

--In Xinjiang Province, where the first discoveries date back to 1947;

--In the Southeast, between the Yangtze Jiang River and the Southeast coast;

--In the Northeast, in the vicinity of Korea.

Those in the Southeast are very likely of the veinstone type, associated with the continental granitic and volcanic rocks of the Jurassic-Upper Cretaceous period, stretching irregularly along a strip 4,000 km long and ranging between 200 and 800 km wide, oriented Northwest by Southeast.

The uranium content of the granites probably varies between 0.13 and 0.2 percent, while that of the volcanic rocks may in some cases be double these amounts.

In the Northeast, two recent discoveries have been announced. One, a rather large deposit, is said to have a uranium content of 0.05 to 0.15 percent,

and the other, a smaller one (around 1,000 tons of U 308), is located some 100 km south of Shenyang, in the province of Liaoning.

The proximity of the Xinjiang deposits to the Soviet border and of the production centers to the Kirghiz Republic explains the notable results obtained with regard to exploration and exploitation of the mines in that region during the 1950's with USSR aid. The "cooling" of relations with the USSR nevertheless had the effect of rendering this sector sufficiently vulnerable to induce the Ministry of Nuclear Industry to systematically prospect that vast territory.

The lack of statistics on the different geological parameters of many existing deposits, and the ambiguity of the available numerical data, are a handicap to any serious attempt to evaluate China's uranium reserves. However, and fully mindful of the need for caution in quoting figures, there is agreement among many experts on the following points:

--Based on the mining resources currently being exploited or in the process of termination, reasonably assured reserves can be estimated at between 800,000 and 900,000 tons of uranium. Adding to these the potential and "theoretically possible" reserves, the total figure could reach 3 million tons of uranium, placing China among the world's principal producers of uranium.

--The majority (around 85 percent) of the deposits are worked underground, and only a few (around 15 percent) are open-pit mined or quarried.

--The selection of the ores to be extracted is done in the case of some mines solely on the basis of radioactivity measurements.

--The ores are processed by various methods, and in particular: For low-grade ores, by lixiviation and iterative wetting with sulfuric acid; and for ores rich in acid-consuming products, by lixiviation using an alkaline mixture of carbonate or bicarbonate of soda, carried out under pressure, and also by biological lixiviation.

--Frequent use is made of ion-exchanger pulse columns and synthetic resins.

Generally speaking, resin-in-pulp and liquid solvents are used to concentrate the solutions.

Special mention should be made of the Hengyang Ore-Concentration Plant in the province of Hunan, which processes around 800,000 tons of ore from four different mines and produces approximately 1,100 tons of uranium annually. This plant has been visited by numerous members of missions.

Despite the imprecision of our data concerning known resources and existing mining operations, it would nevertheless not be absurd to advance an estimate of production at between 2,000 and 4,000 tons annually. While military needs may have been somewhat high during past years, the fact is that, considering the effort that has been deployed, China's uranium stockpile, as of today, could very well be nearing or even exceeding a total of 30,000 tons.

Although these figures are all relative, the Chinese leaders have specifically indicated repeatedly that reserves were sufficient to provision fifteen 1,000 MW(E) reactors for 30 years, while also meeting "domestic needs."

The enrichment of uranium high in U-235 content has been an obligatory stage from the standpoint of military needs. A sizable outlay has therefore been deployed in this domain, and a gaseous-diffusion enrichment plant was built in 1957 with USSR aid, at Lanzhou, in the province of Gansu. Two other enrichment plants are believed to exist, subject, however, to confirmation, in the provinces of Ningxia and Hunan respectively.

As for research in this domain, a sizable and sustained outlay is being made in various sectors. These would seem to include, subject, again, however, to confirmation, enrichment by ultracentrifugation and by laser.

Nevertheless, to implement its nuclear electric power program based on 3-percent enriched uranium, the Ministry of Nuclear Industry has adopted a very open position allowing itself the option of going to foreign sources, should the need be felt to do so, for the supply, in part or in total, of the cores and rechargings of successive stages.

The reprocessing of irradiated fuels also comes under the Ministry of Nuclear Industry. But since this domain is tightly linked to National Defense activities, secrecy has constantly prevailed, to date at least, regarding any opening and exchange of information with foreign sources.

According to various and divergent sources, there are said to be in existence from 3 to 17 (the divergence is wide!) heavy-water plutonium-generating reactors, whose irradiated fuels, after reprocessing, are said to be producing around 300 kg of plutonium annually.

Be that as it may, in this sector as in many others, China is showing sustained interest and curiosity as regards what is being done in countries where fuel reprocessing is being carried on and developed.

China's effort, and the context of its nuclear electric power program, would appear to be directed towards intermediate-term development. This is attested in fact by its on-site intermediate storage installations projects, capable of accommodating some dozen irradiated "recharges"; the decision to reprocess or to not reprocess has, to the best of our knowledge, not been made as yet.

Further regarding the stockpiling sector, we note that proposals were exchanged in early 1984 between a German firm and a Chinese corporation which stated it was prepared to receive in China (in the Gobi Desert), on a remunerative basis, irradiated fuels from the FRG and other European countries. The offer involved some 4,000 tons of fuels to be accrued between 1984 and the year 2000, at a price of $1,512/kg. This price would also

include packaging and transport of the fuel, which would become the property of the Chinese, including the plutonium that would be extracted from it should the latter decide to reprocess it.

The FRG authorities are believed to have reacted negatively to this offer.

V. International Relations

Developed early on--beginning in the 1950's--with the Soviets in particular, these privileged and very wide-ranging relations were interrupted, to be sure, a little less than 10 years later. China, however, succeeded in benefiting sufficiently from this period of cooperation to be able, subsequently and over a long period of autarchy, to develop on its own a significant degree of military power.

It would be 1974-1975 before anyone would begin to see the establishing with the West and in the academic and industrial sectors, at local and national levels, of meetings, congresses, and symposiums in various disciplines, including that of the peaceful use of nuclear energy.

France and Italy were among the first countries to sign with China, in 1975, cooperation agreements in the nuclear domain.

But it was not until the end of the Cultural Revolution that the number of delegations of Chinese scientists and technicians sent abroad on exploratory missions began to multiply. The number of foreign scientists visiting China also took a sharp upturn and included, in particular, university-level Americans of Chinese origin.

Pursuant to these missions, China signed a number of new scientific and technical agreements during the latter half of 1978--in particular, to cite only European countries, with Italy (6 October), FRG (9 October), France (20 October), Great Britain (15 November), and Sweden (4 December). The Chinese Academy of Sciences, under cover of which there emerged during that period the Ministry of Nuclear Industry, signed agreements with its foreign counterparts--with the Max Planck Institute on 15 September 1978, the Yugoslav Academy on 19 September 1978, the Royal Academy of Sweden on 9 October 1978, and the CNRS [(French) National Scientific Research Center] on 20 October 1978. Elsewhere, with Japan, China's scientific exchanges took on increased scope after the signature of the Peace and Friendship Treaty (on 12 August 1978). In September 1978, a large delegation of the Academy of Sciences was received by the Japanese Association for Sino-Japanese Scientific and Technical Exchanges.

The signing of these agreements--the fruits of a politically-oriented initiative at their inception--proved effectively responsive, in the long run, to Chinese aspirations concerned with its opening up to foreign sciences as well as technologies.

China's official turn towards nuclear electric power paved the logical way to the signing with certain countries of specific scientific and technical type agreements in this sector.

It is within this context that a cooperation agreement titled "Memorandum on Cooperation in the Domain of Peaceful Use of Nuclear Energy" was signed in September 1981 between the JAIF [expansion unknown] and the Ministry of Nuclear Industry, providing for exchanges of experts, the organizing of seminars, and exchanges of information, particularly in the domain of nuclear electric power and the use of radioisotopes.

With the Americans, and in about that same period (October 1981), a cooperation agreement was signed between the NRC [(U.S.) Nuclear Regulatory Commission] and the State Commission on Sciences and Techniques, providing on the one hand for exchanges of information in the sectors of safety and operation of nuclear installations, and, on the other, for visits to operating installations together with NRC inspectors.

The FRG has also maintained close ties with China through scientific and technical agreements, which have, beyond any doubt, inherently strengthened relations between the two countries.

Pursuant to the same reasoning, Italy had signed, in 1980, a cooperation agreement with the Ministry of Nuclear Industry.

Relations with France, as has been mentioned above, date back to the years around 1975. Traditional though they were insofar as concerns the methodology applied to their buildup, they were nonetheless innovative as to objectives. The keystones of that initial cooperation were chosen from among the leading-edge technologies: Breeder reactors, vitrification, heavy-ion accelerators...

Negotiations concerning the 900-MW(E) nuclear plants did not begin until 1978. At that time, the French firms FRAMATOME [Franco-American Construction Company] and Alsthom-Atlantique submitted a detailed bid on the Sunan station, near Shanghai, a project on which KWU [Kraftwerke Union] (FRG) had also submitted a bid.

Implementation of the Chinese Economic Readjustment Program in 1979 interrupted and sidelined the realization of the project "to a future date."

Talks were not resumed until April 1980, but on another project, to be located in the province of Canton (the present Daya Bay). In October 1980, during a presidential visit, Messrs Giscard d'Estaing and Zhao Ziyang came to an understanding on terms and conditions to govern the delivery to China of a complete station, sold on a private contract basis. The project stagnated, however, and did not actually get under way again in its present form, or nearly so, until around the beginning of 1982, under the aegis of Mr Li Peng, who was then first vice minister of water resources and electric power.

During that same time, while cooperation between the [French] AEC [Atomic Energy Commission] and the Academy of Sciences was proceeding without any problems in the "basic" domain, many recognized the need to revive cooperation in the applied domain. Thus it was that a new, intentionally open, agreement was signed in November 1982 between the AEC and the Ministry of Nuclear Industry, in support of the Chinese nuclear electric power program.

At about the same time, fully determined to develop their nuclear program, the Chinese authorities approved as of November 1982--for the Daya Bay station--the Franco-British plan calling for the furnishing, without commitment, of nuclear units by FRAMATOME and of conventional units by GEC [General Electric Company]. The client for this station would not be the Ministry of Water Resources and Electric Power, but rather a mixed Sino-Hong Kong company formed by two entities: Guangdong Nuclear Investment Corporation (75 percent) and Hong Kong Nuclear Investment Corporation (25 percent).

However, it was not until during President Mitterrand's official visit to China in May 1983 that a memorandum was signed, stipulating that an ambitious technology transfer program would be undertaken through the furnishing by France, and by FRAMATOME in particular, of four nuclear units, thus enabling China to build, on its own or nearly so, the fifth unit.

Although for the conventional units of the Daya Bay station, Alsthom-Atlantique was outbid by the British, who in fact also signed a memorandum with the Chinese, the same does not hold for the other sections of the Chinese nuclear program, on which Alsthom-Atlantique's chances remain intact.

In its capacity as industrial architect, EDF [French Electric [Power] Company] is to be consulted for assistance in the realization and putting into service of the Daya Bay station, and in the training of the operating personnel.

Thus, from the standpoint of Franco-Chinese relations, it can be said that current negotiations are proceeding in accordance with and under the aegis of the memorandum, while adhering, for the most part, to the agenda proposed by the Chinese side.

Concurrent with the efforts being deployed by France, the Americans and the Germans, principally, are leaving no stone unturned to make known their existence, occupy the terrain, and make life difficult for us. The recent conclusion of the Sino-American Nuclear Agreement Protocol, initialed during President Reagan's visit to China around the end of April, is not in itself of such nature as to simplify Franco-Chinese negotiations. The same is true with regard to the Sino-German agreements signed in Bonn on 6 May. Thus, with respect to the Chinese market, France is no longer the nuclear sector's sole interlocutor, and the advent of such formidable competitors as the Americans and the Germans introduces an added motivation for enhanced effort, imagination and dependability.

It should be noted, moreover, that under its open-door policy, China has also signed cooperation agreements with other countries--with Brazil, for example, as well as with the EEC [European Economic Community].

Lastly, insofar as concerns the AIEA [International Atomic Energy Agency], China was admitted to membership in the Agency in October 1983, and is prepared to take its seat in it, subject to approval by the general meeting this September.

While conforming fully to the Agency by-laws and fulfilling the obligations deriving therefrom, including those in the domain of guaranties and nuclear equipment exports, China has nevertheless reaffirmed its disapproval of the TNP [Nuclear Non-Proliferation Treaty], denouncing its discriminatory character, but approving nevertheless the efforts being made in favor of non-proliferation.

Conclusion

The PRC appears to have definitively turned the page of its behavior towards the world of technology. To succeed in its vast industrial transformation, the Government has adopted and put into operation a mammoth technology transfer program. This program will endeavor to consolidate and modernize the country's industrial structures by way of realization of certain ambitious programs, such as nuclear power, telecommunications and data processing, to cite only the principal ones.

The program is therefore, for the nuclear sector, a comprehensive initiative, certain elements of which have been in place for many years now (particularly for the 300-MW(E) stage), and, for the other sectors, one that must be applied with a view to putting to good account China's locally available assets while introducing from abroad the techniques and equipment it presently lacks.

To profit to the maximum from this "comprehensive initiative," the Chinese leaders are today, more so than yesterday, well positioned to bring competitiveness to bear among the suppliers of nuclear equipment and technologies, particularly since Americans and Germans have now signed nuclear cooperation agreements with China.

The choice of foreign technology, as many like to put it, does not rest solely on criteria of "price and quality," but also on the ability of the industrialists to adapt to the demands imposed by the vast technology transfer program in view. In the present case, coproduction must be approached with a mind-set that is at one and the same time imaginative and responsible, dynamic and open. The enterprises that are able to adapt to this climate will have a decided advantage over their competitors.

While boldness and strictness are also necessary, so are terms and conditions of financing that China can consider the most favorable possible.

In short, while it is still too early to determine precisely the orientation of Chinese nuclear policy and its effectiveness, there are trends of thought nevertheless tending to concur that China is potentially capable of meeting the challenge, as is being attested moreover by the satisfactory development of its national strategy.

As for its electric power stations program, China is decidedly determined to pursue close cooperation with foreign sources. It appears certain at this time that the installation of the stations will proceed concurrently with the implementation of a vast technology transfer operation. But it is not yet clear, in view of the bids being submitted, present and future, involving the putting into operation of complex concepts of organization, what the final decisions will be.

In any case, it would be unwise for any country wanting to do business with China to underestimate this country's capabilities, despite its deficiencies of the moment, and to not believe in its development, the more so since its development is also the key to that of many other countries. The whole is dependent, over the long term, on the maintenance of favorable political conditions.

[Charts, drawing and map follow]:

Table 1

Energy Production in 1983

Lump Coal	Oil	Gas	Hydroelectricity
700.3 million tons	106 million tons	14 billion m^3	85 TWh

Table 2

Energy Consumption in 1983

Total Consumption (in Million tec)	World Rank	Structure of Consumption (Percent)				
		Coal	Oil	Gas	Hydroelectricity	Total
603	3	70	20	2	8	100

Table 3

Installed Networks and Power Capacities (Year-End 1983)

(1) Intitulé du réseau	(2) Puissance installée (MWe)			(3) Provinces couvertes
	(4) Hydroélectrique	(5) Thermique	(6) Total	
Nord-Est (7)	1 700	7 900	9 600	Jilin, Heilongjiang, Liaoning, 1/2 Mongolie
Nord (8)	600	9 600	10 200	Pékin, Tianjin, Hebei, Shanxi, 1/2 Mongolie
Nord-Ouest (9)	2 900	2 900	5 800	Shaanxi, Gansu, Ningxia, Qinghai
Est (10)	3 800	12 700	16 500	Shanghai, Jiangsu, Anhui, Zhejiang
Centre et Sud (11)	6 500	7 500	14 000	Hubei, Hunan, Henan, Jiangxi, Guangdong, Guangxi
Sud-Ouest (12)	3 500	3 200	6 700	Sichuan, Yunnan, Guizhou
Total (6)	19 000	43 800	62 800	

Key:

1. Network Designation.
2. Installed Power (MW(E)).
3. Provinces Covered.
4. Hydroelectric.
5. Thermal.
6. Total.
7. Northeast.
8. North.
9. Northwest.
10. East.
11. Central and South.
12. Southwest.

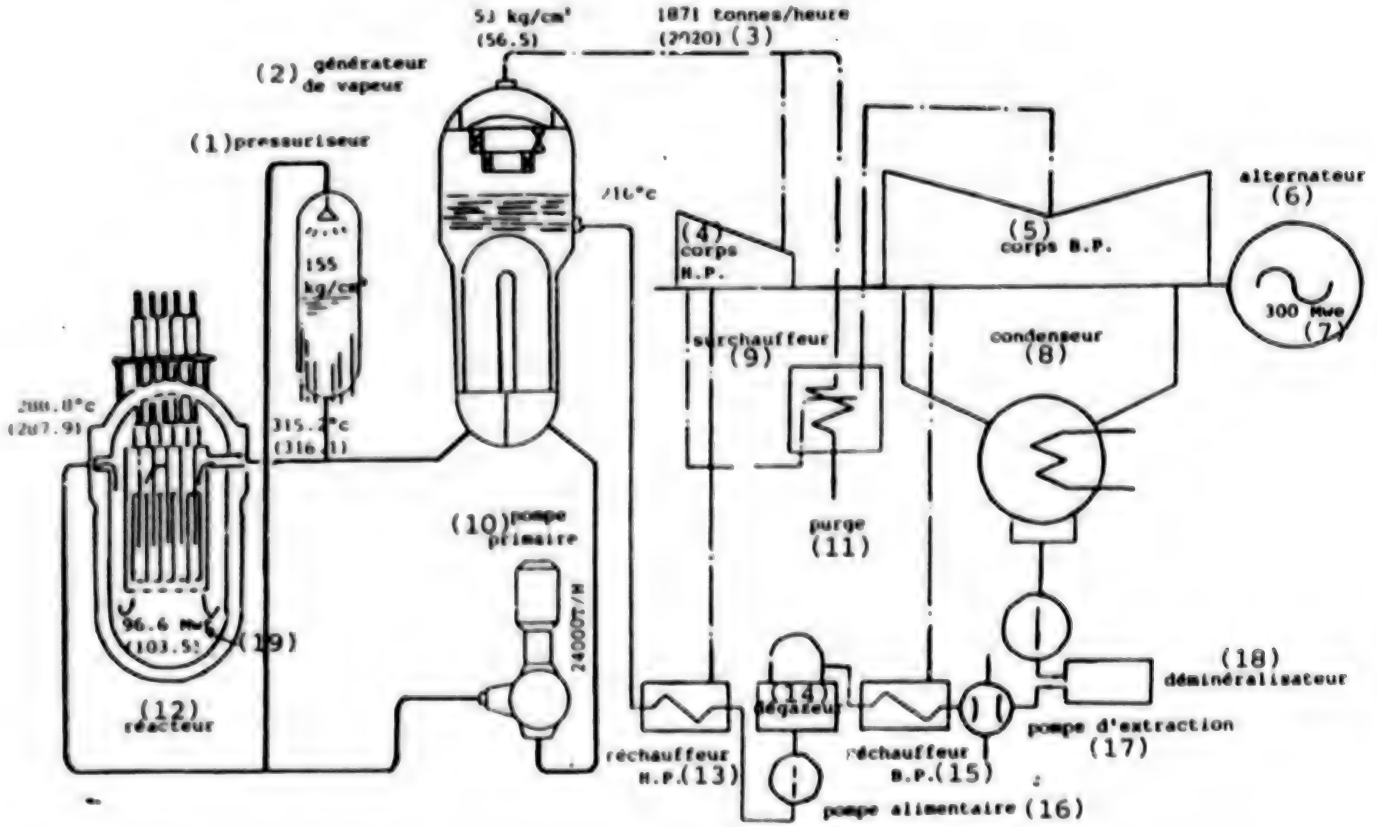


Fig 1 - Schematic of primary and secondary circuits of 300-MW(E) station.

Key:

1. Pressurizer.
2. Steam generator.
3. Tons/hr.
4. High-pressure unit.
5. Low-pressure unit.
6. Alternator.
7. MW(E).
8. Condenser.
9. Superheater.
10. Primary pump.
11. Purge.
12. Reactor.
13. High-pressure reheater.
14. Degasser.
15. Low-pressure reheater.
16. Feed pump.
17. Extraction pump.
18. Demineralizer.
19. MW(T).

China: Map of Uranium Deposits

9238
CSO: 8319/0648

APPLIED SCIENCES

NEW COULOMETRIC METHOD FOR DETERMINATION OF URANIUM WITH TI (111)-TL(111) BIINTERMEDIATE

Lanzhou LANZHOU DAXUE XUEBAO ZIRAN KEXUE BAN [JOURNAL OF LANZHOU UNIVERSITY NATURAL SCIENCES] in Chinese Vol 20 No 3, Sep 84 pp 81-85

[Article by Wang Yingtai [3769 3467 3141], State Factory 279, Chen Aiqiong [7115 1947 8825] and Li Hu Lin [0500 5706 2651]: "A New Coulometric Method for the Determination of Uranium With Ti(111)-Tl(111) Biintermediate"]

[Text] Abstract: A new Coulometric method for the determination of uranium-content is described in this paper. The samples are taken up in concentrated HCl and concentrated H_2SO_4, then treated with H_2O_2 to oxidize all the U ions in various oxidation states into U^{+6}. The amount of U^{+6} is then titrated via a Ti^{+3}-Tl^{+3} biintermediate process in a 6M H_2SO_4 solution containing 0/1M Tl^{+1} and 0.5M Ti^{+4} with a platinum electrode by Coulometric method. The results of analyses on standard uranium samples with this procedure showed an accuracy better than $\pm$0.1 percent for samples with uranium-content in minigrams and an accuracy around $\pm$0.4 percent for samples containing micrograms of uranium. This method provides a much faster means than gravimetric analysis for uranium determination yet with comparable accuracies.

Numerous procedures using the Coulometric titration for determining uranium-contents have been described. In the procedure reported by Goode et al[1], UO_2^{+2} was first reduced by an excess of Ti^{+3} in the presence an aminosulfanilic acid in H_2SO_4-HNO_3, the unreacted Ti^{+3} was then oxidized with HNO_3; Fe^{+3} was subsequently added to oxidize UO^{+2} to give an equivalent amount of Fe^{+2}. The quantity of Fe^{+2} was then determined by electrogenated Ce^{+4} by Coulometric method to give the uranium-content. Other procedures involve the reduction of UO_2^{+2} to U^{+4} by mercury amalgamated active metals followed by Coulometric titration of U^{+4} with an electrogenated oxidizing agent[2]. All the literature procedures go through complicated steps. A method, reported by Lingane[3], determines the uranium-content by direct titration with electrogenated Ti^{+3}. However, the results of our experiments showed that because of the flat titration curve obtained as a result of the slow reaction rate between small amounts of uranium and titanium, the end point cannot be determined accurately, yielding large errors. Therefore, this drawback of Lingane's method excludes its use on low uranium-content samples. In this paper, a new Coulometric titration for uranium determinations, i.e., a Coulometric method involving Ti(III) and Tl(III) dual intermediates is described. The analysis is carried out in a 6M H_2SO_4 solution containing

0.5M Ti^{+4} and 0.1M Tl^{+1}; the platinum electrode reduces Ti^{+4} to Ti^{+3} and U^{+6} to U^{+4}, the polarity of the current is then reversed, making the platinum electrode the anode to oxidize Tl^{+} to Tl^{+3}; the Tl^{+3} ion thus obtained oxidizes the excess titanium(III) and the end point is determined potentiometrically. The equivalence difference between Ti^{+3} and Tl^{+3} gives the equivalents of uranium and through calculation the uranium-content is found.

The advantage of this procedure that the oxidizing and reducing agents are generated at the electrode, thus, eliminating the steps for introducing auxiliary reagents, makes it simple to carry out. In addition, the shape of the titration curve is greatly improved allowing accurate detection of the end point. The result of analysis on pure uranium samples showed that this procedure gives an average accuracy around 0.05 percent. For analyzing uranium samples, this Coulometric titration procedure gives uranium-contents consistent with those obtained by gravimetric analysis.

I. Apparatuses and Reagents

Instruments and Reagents. As described previously[4], Ag/AgCl electrode is used as the reference electrode. The electrical potentials are measured against the reference electrode unless otherwise specified in accompanying figures.
Thallium(I) Carbonate: analytical grade.

Sulfuric Acid, 6M: analytical grade.

Titanium(IV) Sulfate: 15 percent solution. If $Ti(SO_4)_2$ is not available, the solution can be prepared from $Ti_2(SO_4)_3$ by either of the two following procedures:

1. Electrolytic Oxidation Method: To 100mL $Ti_2(SO_4)$ solution (containing 15 percent $Ti_2(SO_4)_3$ and 24 percent sulfuric acid) placed in a 100mL beaker was added 20mL of concentrated sulfuric acid. The electrolytic oxidation was conducted with a platinum electrode as the anode and a coiled wire, the cathode. The two electrodes were separated by a porous membrane. A 500mA current was applied and continued for another 5 minutes after the violet color of the trivalent Ti ion had disappeared. After the oxidation was completed, the system was flushed with purified nitrogen or argon; the volume of the solution was reduced with heating in the absence of oxygen to 100mL. The solution so obtained was 1M in Ti^{+4} and 6M in sulfuric acid.

2. Hydrogen Peroxide Oxidation Method: To a 1L $Ti_2(SO_4)_3$ solution was added 200 mL concentrated sulfuric acid. The solution was then treated with H_2O_2 dropwise until the violet solution turned into a red one. The excess H_2O_2 was titrated with a dilute $Ti_2(SO_4)_3$ solution until a yellow color developed. The solution was then concentrated with heating to 1L and cooled to give a Ti^{+4} concentration of 1M and sulfuric acid, 6M.

Standard Uranium Solution, 10.00mg per mL: To an accurately weighed U_2O_3 sample (5.896 g, spectral grade) were added concentrated HNO_3(5 mL) and sulfuric acid (20 mL). The solution was heated until a white smoke was observed. It was cooled to room temperature, then, transferred to a volumetric flask containing water and diluted to the mark.

II. Experimental

1. The Electrolysis and Current Efficiency of Ti(III) and TL(III) in 6M H_2SO_4.

This laboratory had made detailed studies on the current efficiency for the electrolysis of Tl(III) in 6M H_2SO_4[5]. There had been different reports on the current efficiency for the electrolysis of Ti(III). We did not experiment with electrolysis using mercury electrode as the cathode. Because of the higher hydrogen overvoltage on carbon electrodes and the simplicity to operate of platinum electrodes, we studied the current efficiencies for electrolytic reduction of Ti(III) using these two kinds of electrodes. Our results indicated that both carbon and platinum electrodes can electrolytically generate Ti^{+3} from Ti^{+4} with 100 percent current efficiency. However, we did not carry out any further studies using the carbon electrode because it was not as simple to use as the platinum electrode, also the carbon electrode tended to flake off due to the oxidation of carbon during the electrolytic reduction of Ti(IV). The current- current density curve for the reduction of Ti(IV) is given in Figure 1.

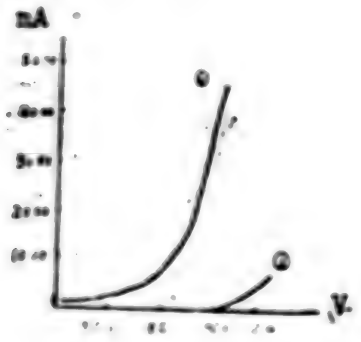


Fig. 1 Reduction of Ti^{+4} using platinum electrode as the cathode in 6M H_2SO_4.
1. 0.5M Ti^{+4} + 6M H_2SO_4
2. 6M H_2SO_4 with electrode surface of 11 cm^2

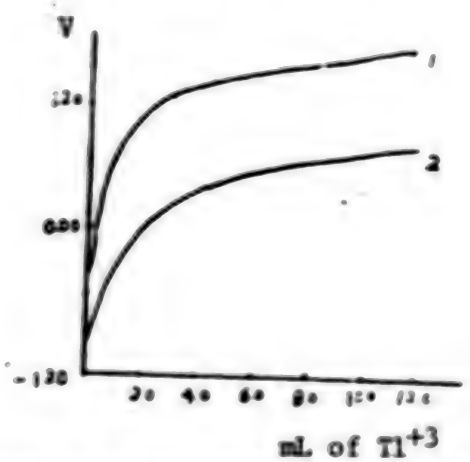


Fig. 2 Direct potentiometric titration of UO^{+2} with Ti^{+3}.
1. with UO^{+2}
2. without UO^{+2}

As shown in Figure 1, curve 1 and curve 2 are far apart in a solution of 6M sulfuric acid and 0.5M Ti^{+4} when the current density is kept above 50.00mA/11 cm^2. This observation suggests that little residual current remained in the electrolytic solution during the electrolytic reduction of Ti^{+4}, indicating a nearly 100 percent current efficiency and led us to employ the platinum electrode for subsequent studies.

We also observed that when the Ti^{+4} concentration dropped below 0.3M and H_2SO_4, 8M, the current efficiency decreased.

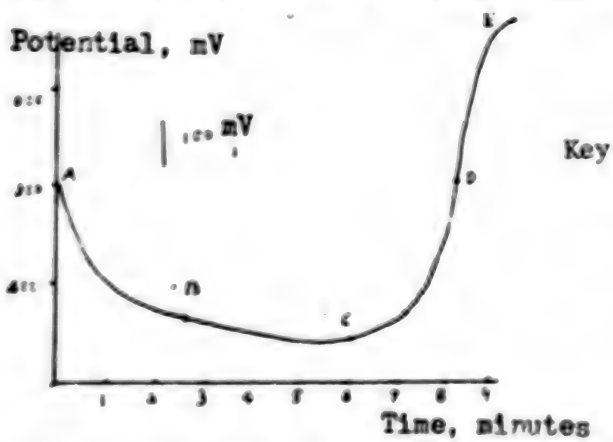
Considering the Tl^{+3}/Tl standard potential, a possible side reaction during the oxidation of excess Ti^{+3} by Tl^{+3} is the concomittant oxidation of UO^{+2} and would result in a lower experimental value for the uranium-content. In order to determine whether the undesired oxidation of UO^{+2} would take place or not under the experimental conditions, we prepared UO^{+2} samples and carried out Coulometric titration of UO^{+2} with standard Ti^{+3} solutions. The results are given in Figure 2.

Figure 2 shows, in both cases, with or without UO^{+2}, with the introduction of a small amount of Ti^{+3}, the potential went up immediately. This rise in potential was caused by the high potential of Tl^{+3} since no break in the voltage-volume curve was observed. Curves 1 and 2 resembled each other in shape, only differ in their initial potentials on the voltage-axis. This observation clearly showed that the oxidation of Tl^{+2} by Ti^{+3} would not occur under the experimental conditions. A latter experiment (see segment C in Figure 3) also proved that during the oxidation of Ti^{+3} with Tl^{+3}, no accompanying oxidation of UO^{+2} taking place.

2. The Coulometric Titration of Uranium with the Ti(III)-Tl(III) Biintermediate

To a beaker were added in order, a known amount of UO_2^{+2} standard solution, 6M H_2SO_4, 0.5M Ti(IV) and 0.1M Tl(III). The current was applied to generate an excess of Ti(III) using the platinum electrode as the cathode (The amperage varied with the concentration of UO_2^{+2}, generally, was smaller than $4mA/cm^2$). The polarity of the current was then reversed, converting the platinum electrode into the anode for the electrolytic oxidation of Tl(I) to give Tl(III). The unreacted Ti(III) was then, titrated with Tl(III). The titration curve so obtained is given in Figure 3.

Fig. 3 Ti(III)-Ti(III) Biintermediate Coulometric Titration of Uranium



Key:

A. The starting point of the electrolytic reduction of Ti(IV)
B. The theoretic end point of the titration of UO^{+2} with Ti(III)
D. The theoretic end point of the oxidation of Ti(III) by Tl(III)

UO_2^{+2} : 2.00mg
Amperage: 10.00 mA

The titration curve in Figure 3 indicated that the U(VI) was titrated directly by the electrolytically generated Ti(III). That there was no discernable break in the titration curve even with a sample size of 2.00 mg of UO_2^{+2} with the potential kept falling showed that the redox rate of Ti^{+3} and UO_2^{+2} was not fast enough. This slow reaction rate explains why the accuracy of the Lingane method cannot be improved. However, in our procedure, UO_2^{+2} was reduced by a large excess of Ti(IV) generated electrolytically, the unused Ti(IV) was then back-titrated by Tl(III) obtained by electrolytic oxidation, the result is a steep potential rise of more than 300 mV, giving a distinct end point. The results of the analyses of uranium samples with this procedure are listed in Table 1.

As shown in Table 1, our procedure determines the uranium- content with great accuracy, giving a maximum error of lower than $\pm$ 1 percent for samples containing 1 mg uranium.

3. Interferences

The presence of strong oxidizing agents, which are capable of oxidizing Ti(III) as indicated by their redox potentials will interfere the uranium determination; however, if the ions of these elements are in their lower oxidation states, such as Mn^{+2}, V^{+4} and Cr^{+3}, since they cannot be oxidized into higher oxidation states during the electrolytic processes, the presence of these ions will not interfere with the analysis. Other common elements, e.g., alkali metals, alkaline earth metals, lead, nickel, cadium, zinc, tin, etc., do not interfere.

The presence of silicates, small amounts of nitrates and perchlorates in a diluted states in the samples do not interfere. Because of its ability to precipitate Tl^{+} to form TlCl, which absorbs UO_2^{+2}, the presence of Cl^{-} tends to lead to lower experimental values of uranium- content. Since Fe(III) oxidizes Ti(III) resulting in a flatter titration curve for the backtitration of Ti(III),[6] therefore, if large quantities of iron are present, they should be removed first. We followed the sodium carbonate-addition procedure to separate UO_2^{+2} from other species and obtained good analytical results.

4. The Coulometric Titration of Uranium in Samples

An accurately weighed uranium-containing sample (2.00 m) was suspended in a small amount of water; 5 mL concentrated HCl and 10 mL concentrated H_2SO_4 were added. The mixture was heated to dissolve the solid sample until a white smoke developed. The solution was treated with 15 mL 3 percent H_2O_2, then neutralized with solid Na_2CO_3. More Na_2CO_3 (2 g) was added. The mixture was heated to boil and filtered. The filtered insoluble material was washed thoroughly with water. The pooled filtrate was transfered quantitatively to a 250 mL volumetric flask and diluted with more water to the 250 mL- mark. Aliquots were removed from the standard solution for Coulometric titrations. The results are presented in Table 2.

Table 1. Results of Uranium Determination With Ti(III)-Tl(III) Biintermediate Coulometric Titration

Wt. of U (mg)	Amperage (mA)	Time for Electrolytic Oxidation of Tl(I), (sec)	Time for Electrolytic Reduction of Ti(IV), (sec)	Wt. of U Found, (mg)	Errors (mg)	Average Errors (%)
100.00	50.00	2,500.00	879.74	99.945	- 0.05	- 0.04
			879.77	99.943	- 0.06	
			879.13	99.982	- 0.02	
50.00	50.00	1,620	810.5	49.943	- 0.13	- 0.11
			810.0	49.946	- 0.07	
			810.7	49.921	- 0.15	
25.00	50.00	810.0	405.5	24.98	- 0.07	- 0.07
			405.5	24.98	- 0.07	
			405.5	24.98	- 0.07	
10.00	20.00	810.0	404.0	10.02	+ 0.17	± 0.07
			404.2	10.01	+ 0.12	
			404.9	10.99	- 0.07	
5.00	10.00	810.0	405.8	4.987	- 0.20	± 0.12
			405.0	4.996	- 0.08	
			405.0	4.996	- 0.08	
1.00	10.00	287.2	206.2	0.999	- 0.10	± 0.54
		250.7	168.5	1.014	+ 1.4	
		251.0	170.3	0.996	- 0.4	
		256.4	175.7	0.996	- 0.4	
		249.2	168.5	0.996	- 0.4	

Table 2. Results of the Coulometric Titration of Uranium- Containing Samples

Samples	U-Content	U-Content Found		Errors
1*	56.00	55.97 55.97 55.97 56.01 56.03	55.99	+ 0.02
2*	45.97	45.75 45.75 45.80 45.78 45.75	45.78	- 0.4
3**	0.1g 0.7% sample + 10mg U were added	0.0268mg 0.0271mg 0.0270mg	0.0269	--

* A composite sample, according to the results of spectroscopic analysis, it contains: U, around 0.1 percent; Th, 0.015 percent; large quantities of SiO_2 and Al and micro amounts of Ti0·0$_x$, Sn0·0x, Pb0·0x, V, Cu and Ni.

References

1. G. C. Goode, Anal. Chim. Acta., 37, 445 (1967).
2. Wang Yi tai, Chen Ai un and Li Hu lin, The Analytical Chemistry Laboratory, in preparation.
3. J. J. Lingane, Anal. Chim. Acta., 50, 1 (1970).
4. Li Hu lin, Anal. Chem. (China), 8454 (1982).
5. Zuo Zong qi, Chen Tong yueh, Li Hu lin and Gu Cheng shan, Journal of the Institutes for Higher Education, Natural Sciences, 116 (1966).
6. Li Hu lin et al, Journal of Lanzhou University, Natural Sciences, 18(4), 93 (1982).
7. Shi Hui ming et al, Chemical Analysis of Rare Elements, Vol 2, p 265, (in Chinese), People Education Press (1964).

12817
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APPLIED SCIENCES

ESTIMATION OF MAXIMUM GROUND ACCELERATION OF SAFE SHUTDOWN EARTHQUAKE (SSE) FOR SOME CHINESE NUCLEAR POWER PLANT SITES

Chengdu HE DONGLI GONGCHENG [NUCLEAR POWER ENGINEERING] in Chinese Vol 5 No 5, Oct 84 pp 24-27

[Article by Wang Demin [3769 1795 3046]]

[Excerpts] Estimation of the maximum ground acceleration of safe shutdown earthquake (SSE) of nuclear power plants is an urgent task of the structural engineer, seismologist and geologist in designing and constructing a plant. This article presents a preliminary discussion on the essential parameters of several nuclear power sites in China.

Nuclear Power Plant Site, SSE Estimation and Maximum Acceleration

1. Presentation of Question

Nuclear power plants and thermal power plants have their similarities, but also some major differences.[1,2] In a nuclear power station the reactor contains a large quantity of fissionable materials and its temperature is very high when in operation, thus its structure, equipment and its parts must not be allowed to have any deformation or displacement under any circumstances in order to insure safe operation. Especially in case of an accident, safe shutdown and maintaining the safe shutdown status must be guaranteed so that no above-limit radioactive materials leak into the surrounding environment and pollute it. Therefore, insuring safety is a primary concern in the construction of nuclear power plants.

Because an earthquake is the biggest potential threat to the safety of a nuclear power plant, earthquake analysis and earthquake resistance engineering become the highest priority in safety technology,[3-5,7] While insuring safety, the investment cost of building a nuclear power plant must be weighed too. In the process of designing and building the plant and its equipment, components are classified--according to their importance--into third and fourth class to incorporate earthquake resistance features.[6,7] For structures, equipment, systems and parts which are not related to nuclear safety, general "industrial and civilian construction earthquake resistance specifications" are used, but for components related to nuclear safety two specific standards, Safety Shutdown Earthquake (SSE) and Operating Basis Earthquake (OBE) must be defined.[8-10]

Because SSE plays a vital role in the safety and investment consideration of a nuclear power plant, it is sometimes called Design-Basis Earthquake (DBE).[11] In fact, while both SSE and OBE are design-basis earthquake, SSE has a larger influence on the safety and investment of a nuclear power plant. Consequently, when a comparative study is done on the technology and economy of site feasibility, when analyses are done on the suitability of stock equipment to be ordered or new equipment to be manufactured for a specific plant site, designs being drawn of building structures to house the reactor and generator, or when existing standard designs' suitability to a specific plant site studied, first of all SSE must be defined.

In view of the selected reserve sites in China, most of them are in low earthquake magnitude areas, that is in the areas $\leq$ 7th degree on the 1:3 million national earthquake magnitude map. However, the recorded history of earthquake activity all earthquake areas show similar characteristics of a cycle of relatively inactive periods and relatively active periods. On the basis of earthquake activity cycle, the latter half of the lifetime of a plant of a certain plant site will lapse into a relatively active period of the earthquake activity cycle. Furthermore, another special characteristic of nuclear power plants is that after they reach the end of their operational life, their radioactive material decay period lingers on for a long time. In addition, heat corrosion, nuclear corrosion and chemical corrosion will make much of its equipment and pipes brittle and aged, and a nuclear power plant remains a source of radioactivity when it is shut down or its equipment is being replaced. Therefore in assessing a nuclear power plant's earthquake engineering, two time spans, the 40 to 50 year lifetime of a plant (including the beginning stage) and the relatively long period after cessation of operations, must both be taken into consideration. These two time spans do not coincide with the commonly adopted 100-year earthquake magnitude cycle in China. In this respect, this author believes that earthquake magnitude study is a prerequisite. In foreign countries fault fracture length is used to estimate the potential impact of earthquake magnitude upon a plant site. However, China has the longest recorded history of earthquakes and abundant historical reference materials; thus, this task can be accomplished by means of studying the earthquake history, the geology, the geophysics, and the earthquake engineering of each individual earthquake area.

2. Estimating SSE

In estimating the SSE, the method of definite parameters or the method of probability are generally used.[3,14,8] The purpose is to use definite physical quantities to illustrate the activity of ground vibration. Given ground maximum acceleration as a_{max}, response spectrum as S_a, the earthquake history and duration as Δ, etc. The most important factor among them is the ground maximum acceleration a_{max}. The following is a discussion of the factors.

Estimating a Certain Chinese Nuclear Power Plant Site's SSE a_{max}

The borders of the seismological tectonics of the region where the plant site is located are quite distinct. Based on a comprehensive study of the trend of the seismological activities, three potential earthquake threat spots around

the plant site are identified and their potential maximum magnitudes are estimated. Using the estimation method of averaging the ground maximum acceleration values on bedrock presented by Schnabel and Seed in 1973 (from Figure 1)[15] and another method of establishing a diminishing curve based on the more than 900-year-long earthquake record of the region, the results of the two estimates are in accord.[16] Below, only the values of relative larger impact on the plant site are listed in the table:

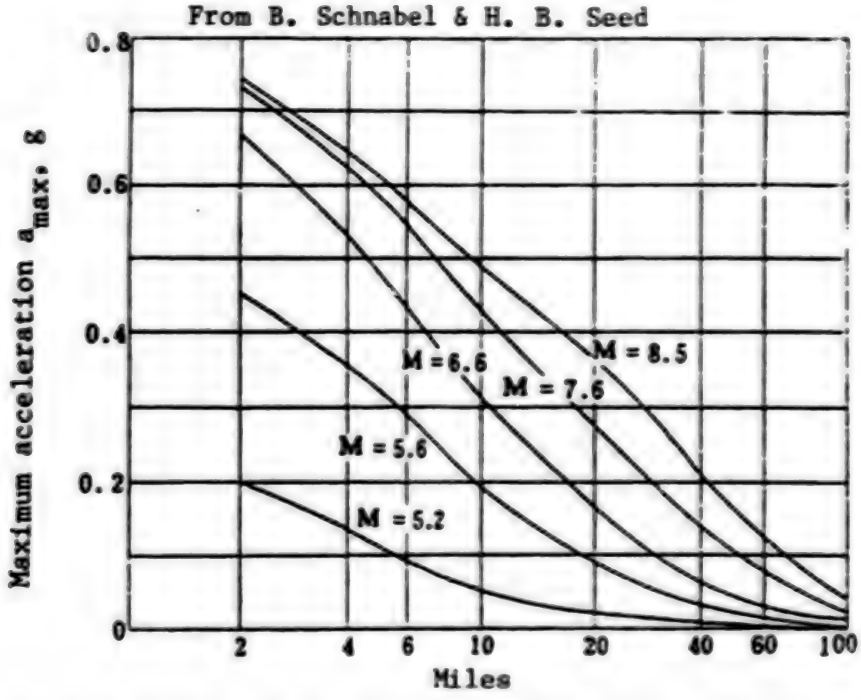

Figure 1. The Average Values of the Ground Maximum Acceleration Rates on Bedrock

Table. I_0, a and I_1 Values of Plant Site Estimated on the Basis of Fault Fracture Length

Number	Estimated length L, km	Estimated minimum distance from plant site Δkm	Estimated seismic level M	Calculated intensity I_0	a, %g	Determined from diminishing curve I_1
55	23	20	5½ 6	7 8	0.12 0.18	VII VII
45	10	22	5	6	0.02	< VI
47	15	20	6	8	0.20	VII
53	17	19	6	8	0.19	VII
59—1	20	22	6	8	0.18	VII
59—2	40	40	6½	9	0.16	VII
5&6	60	22	7	9	0.30	VII

Note: Estimation parameters not verified

3. Estimating SSE a_{max} of Another Chinese Nuclear Power Plant

The borders of semismological tectonics of the region of the second plant site are less distinct, but there are reference materials of about 500-year-long seismological history, current microseismographic materials, seismic diminishing rule materials, and more detailed analytical materials of seismological activity trends and their threat. Based on all above materials the estimate of SSE a_{max} is 0.15 g and OBE a_{max} is 0.10 g. The verified values can be obtained from Figure 1 for the estimated values. The seismological tectonics illustrations are omitted here.

3. Conclusion

Defining the SSE of a nuclear power station is of vital importance. It is a matter of design and also a matter of policy. It requires the leadership, the technological working staff, the nuclear management agency, and the production unit to work together to do the in-depth, detailed studies and analyses with extraordinary caution and highest precision. China is a country with frequent and strong earthquakes. It is different from the cases in France and Germany, but similar to that of Japan and the United States. However, we must do our own analysis and assessment on the basis of the unique conditions of each individual region in our country.

REFERENCES

1. Wang Demin, "Nuclear Technology in Foreign Countries [GUOWAI HEJISHU]," 4, 92, 1981.

2. Wang Demin, "ENGINEERING PROSPECT [GONGCHENG KANCHA]," 4, 30, 1983.

3. D.K. Skula, et al., "Semismological Engineering in Foreign Countries [GUOWAI DIZEN GONGCHENG]," 1, 25, 1981.

4. Wang Demin, "Selected Translations on Seismology and Geology [DIZHEN DIZHI YICONG]," 5(3), 11, 1983.

5. O. Saenz, Ridruejo, et al., translated by Zhou Suyuan, et al., NEW FOREIGN TECHNOLOGY IN ENGINEERING GEOLOGY [GUOWAI GONGCHENG DIZHI XIN JISHU], selected translations of papers presented in the 3d International Engineering Geology Conference, 91, 1980.

6. N.M. Newmark, et al., AT (49-24)-0116, 1978.

7. I.A. Ea, Safety Series N50-SG-S2, 1979.

8. Wang Demin, HYDROGEOLOGY AND ENGINEERING GEOLOGY [SHUIWEN DIZHI GONGCHENG DIZHI], 2, 8, 1981.

9. Gu Xun and Wang Demin, SCIENTIA GEOLOGICA SINICA [DIZHI KEXUE], 4, 408, 1982.

10. Wang Demin and Gu Xun, "Prospecting Science and Technology [KANCHA KEXUE JISHU]," 1, 39, 1984.

11. Xu Zhixin, "Collection of Papers Presented at the National Seismological Engineering Conference (I) [GUANGUO DIZHEN GONGCHENG HUIYI LUNWEN JI (I)], Te-6," 1984.

12. Wang Demin, "Collection of Papers Presented at the National Semismological Engineering Conference (I), JIAO-2 [0074-0059]," 4, 1984.

13. P.C. Rizzo, translated by Wang Demin, "Selected Translations on Seismology and Geology," 3(3), 18, 1981.

14. Wang Demin, et al., "Proceedings of the 4th International Congress IAEG," Vol 8, 1982, p 205.

15. P.B. Schnabel, et al., "Bulletin of the Seismological Society of America," 63(2), 501, 1973.

16. Lu Rongjian, "Research Report of Engineering Mechanics Institute of the Chinese Academy of Sciences (79011)," 5, 1979.

17. Wang Demin, "Electrical Power Construction [DIANLI JIANSHE]," 3, 42, 1984.

12787
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APPLIED SCIENCES

BURN-UP OF 300 MWE PWR POWER STATION ANALYZED

Beijing HE KEXUE YU GONGCHENG [CHINESE JOURNAL OF NUCLEAR SCIENCE AND ENGINEERING] in Chinese Vol 4 No 3, Sep 84 pp 276-281

[Article by Cheng Pingdong [4453 1627 2639] and Shao Tianwei [6730 1131 0251] of the 728 Research and Design Institute: "3-D Nodal Analysis of Burn-up Physics for 300 MWe PWR Power Station"]

[Text] I. Introduction to the NB Burn-up Program

The burn-up analysis of a PWR power station is a 3-D dynamic problem. The improved nodal method[1] has sufficient accuracy and speed and may be used in the routine calculation of the burn-up process. In the 3D-NB-1 program, the physical, thermodynamic, and hydraulic calculations are coupled. The dependence of the thermodynamic and hydraulic parameters of the two groups of cross-section of the nuclide in the nodes is treated with a polynomial. For the ith nuclide in the jth node, the thermal cross-section σ^i, the fast neutron moderation cross-section of water σ_{rj}, and the fast neutron absorption cross-section of U-238 can be computed respectively with the following equations:

$$\sigma_j^i = \sigma_o^i + \sigma_{m1}^i \Delta T_{mj} + \alpha_{m2}^i \Delta T \sigma_j^2 \quad (1)$$

$$\sigma_{rj} = \sigma_{ro} + C_1 \Delta N_j^{-1} + C_2 \Delta N_j^{-2} + C_3 \Delta N_j^{-3} \quad (2)$$

$$\sigma_{aj} = \sigma_{alo} + \alpha_f^c \Delta (T_{fj})^{1/2} + \alpha_{m1} \Delta T_{mj} \quad (3)$$

where σ_o^i, σ_{ro} and σ_{alo} are the reference values of the cross-sections corresponding to a moderator temperature reference of T_{mo} or a water density reference N_o and effective fuel temperature reference T_{fo}.

$$\Delta T_{mj} = T_{mj} - T_{mo},\ \Delta N_j^{-n} = N_j^{-n} - N_o^{-n}\ (n = 1,2,3),\quad \Delta (T_{fj})^{1/2} = (T_{fj})^{1/2} - (T_{fo})^{1/2}$$

The moderator temperature of the jth node T_{mj}, the water density N_j and the effective fuel temperature T_{fj} are obtained by physical, thermodynamic and hydraulic iteration at each burn-up step. The temperature coefficients of the cross-sections α_{m1}^i, α_{m2}^i, C_n, α_f^c and α_{m1} are all precalculated known values. The burn-up corrections of the thermal cross-section, the G-factor of the flammable and poisonous material and the Pu-240 fast cross-sections are made automatically according to a predetermined relationship. In order to improve the computation efficiency, the equilibrium cycle may also be computed

using the two-dimensional nodal fuel management program 2D-NB-1. In this program, the entire reactor core is treated as an axial section.

II. Description of the Reactor Core and the Calculation Conditions

Figure 1 shows schematically the reactor core layout of the 300 MW prototype PWR power station. In the radial plane, the nodes are divided according to the fuel modules and the reactor core is divided into 14 equal parts in the axial direction. The nodes are approximately cubic in shape. The fuel enrichment is divided into three regions in the radial direction. The flammable and poisonous rod has a different distance to the reactor top than to the bottom, and homogenizing processes are made in the nodes in the 15th and the second sections respectively.

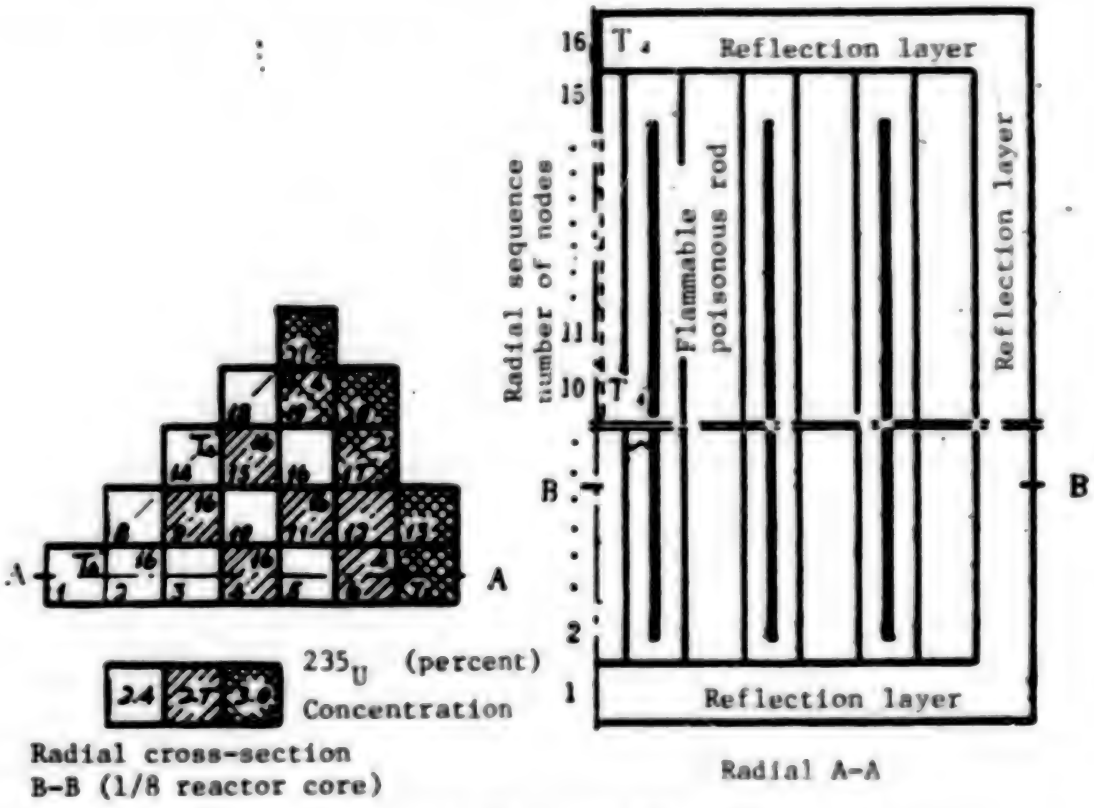

Figure 1. Schematic Diagram of Reactor Core Layout

In the rod-controlled burn-up, the initial insertion depth of the main regulation module T_4 of the control rod is approximately 2/5 of the reactor core height. In the burn-up process the control rod is gradually raised until only 0.25 percent is engaged at the end of the burn-up.

Using the 3D-NB-1 program, burn-up calculations were made for the first cycle of the reactor core under four different conditions; no control rod and no feedback, no control rod and with feedback, with control rod and no feedback, and with control rod and with feedback. Using the 2D-NB-1 program, equilibrium cycle calculations were made for the condition of no control rod and no feedback, the fuel change enrichment of the first cycle was the same as that of region III. The refueling was conducted in a three-zone mode.[2]

In order to simplify the computation and to compare with the no-feedback and time and spatial independent temperature results, we assumed that the thermal conductivity of the gas between the fuel cladding and the core block remained constant and independent of the burn-up and that heat exchange by contact never took place. This approximation is acceptable when the average fuel temperature is low, the burn-up depth is small and hence the fission gas release is low and the core block swelling is not serious.

III. Calculation Results and Discussion

3.1 Steady state reaction

Figure 2 shows the variation of the effective breeding coefficient and the critical boron concentration as a function of the burn-up depth during the first cycle with control rod and feedback. Table 1 compares the initial reactivity and the decreasing reactivity for four different calculation conditions.

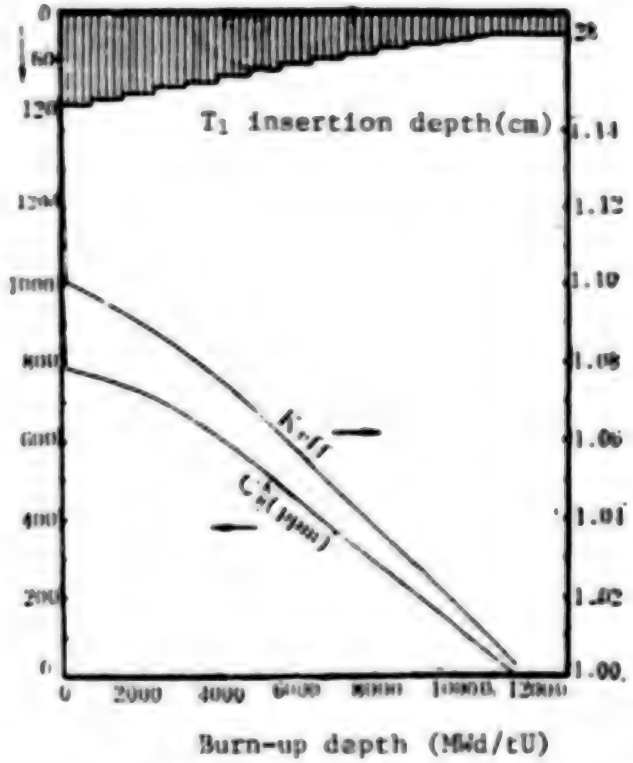

Figure 2. Variation of the Effective Breeding Coefficient K_{eff} and the Critical Boron Concentration C_B^k as a function of burn-up

As can be seen from Table 1, the rate of decrease of the reactivity with rod and with feedback is the lowest. After the xenon equilibrium is established, the reactivity decreases an average of 8.57×10^{-5} ΔK for every 100 MWd/TU of burn-up. The feedback effect evens out the power distribution and the rod lift makes the burn-up distribution approaching uniform. Table 1 also shows

that the reactivity without feedback is greater than that with feedback. This is because the volume average over the entire reactor of the effective temperature of the fuel nodes with feedback is used in the calculation without feedback. If the initial reactivities of the two cases are to be equal, then, the fuel Doppler effect may be used in estimating the average effective fuel temperature of the reactor in the no feedback case and it would be 150°C higher than the volume average temperature mentioned above. Such spatial effects decrease considerably as the xenon equilibrium is established and the burn-up deepens.

Table 1. Initial Reactivity and Rate of Decrease of Reactivity

Performance \ Calculation conditions		Burn-up without rod		Burn-up with rod	
		No feedback	feedback	No feedback	feedback
Initial reactivity (No boron no rod) percent ΔK	No Xenon	14.44	14.00	14.44	14.00
	Equilibrium Xenon	10.22	10.03	10.17	10.11
Rate of decrease reactivity 10^{-4}ΔK/100 MWd/TU		8.79	8.64	8.60	8.57

Figure 3 shows the variation of the reactivity in the first five cycles. Figure 4 shows the difference between the rate of decrease of the reactivity in the 3-D and 2-D calculations without feedback and without rod. As can be seen, the 2-D rate of decrease is 6 percent too small.

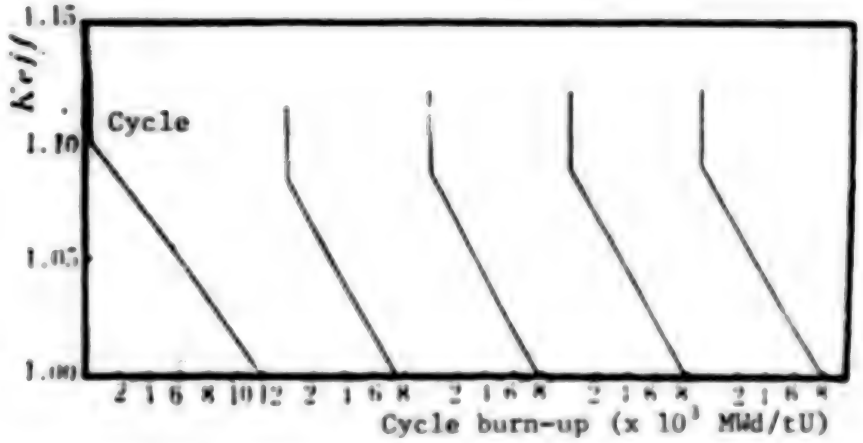

Figure 3. Reactivity as a Function of Burn-up for the First Five Cycles

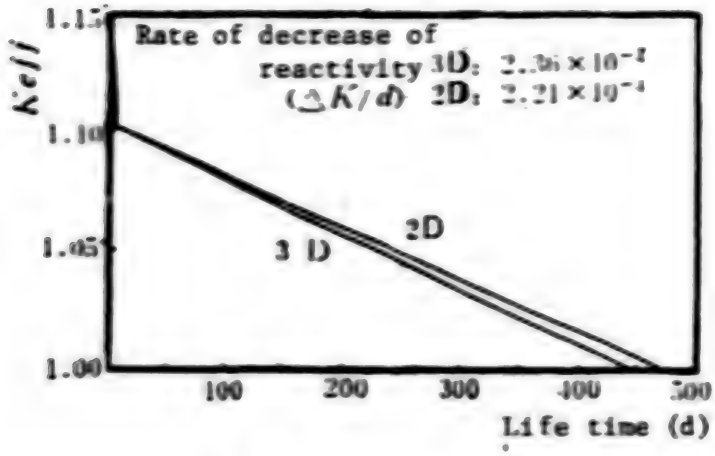

Figure 4. Rate of Decrease of the Reactivity in 3-D and 2-D Calculations

3.2 Power distribution

Figures 5-7 show the nodal normalized power distribution and the assembly normalized power distribution of the initial, middle and late stages of the first cycle burn-up with feedback and with rod. Table 2 shows the nodal normalized peak power and the assembly normalized peak power at different burn-up stages under four different calculation conditions.

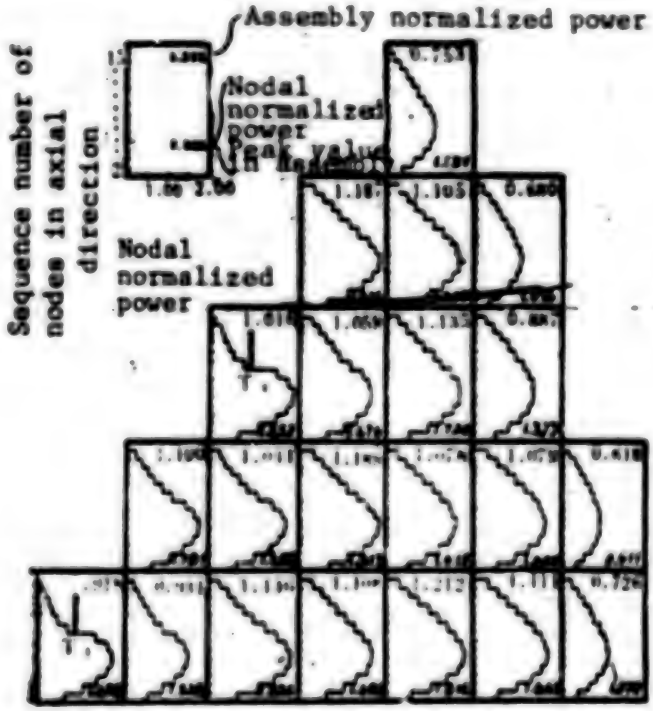

Figure 5. Nodal Normalized and Assembly Normalized Power Distribution at the Initial Stage of the First Cycle

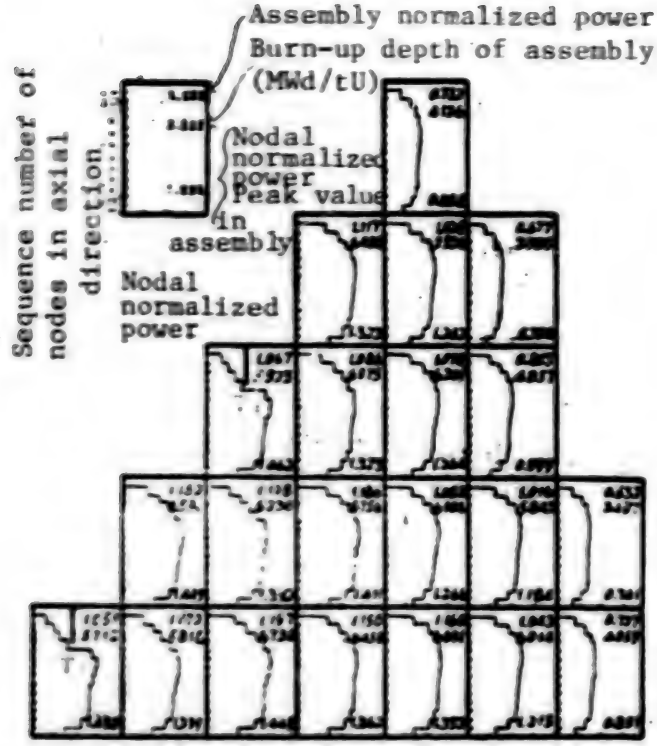

Figure 6. Nodal Normalized and Assembly Normalized Power Distribution at the Middle Stage of the First Cycle

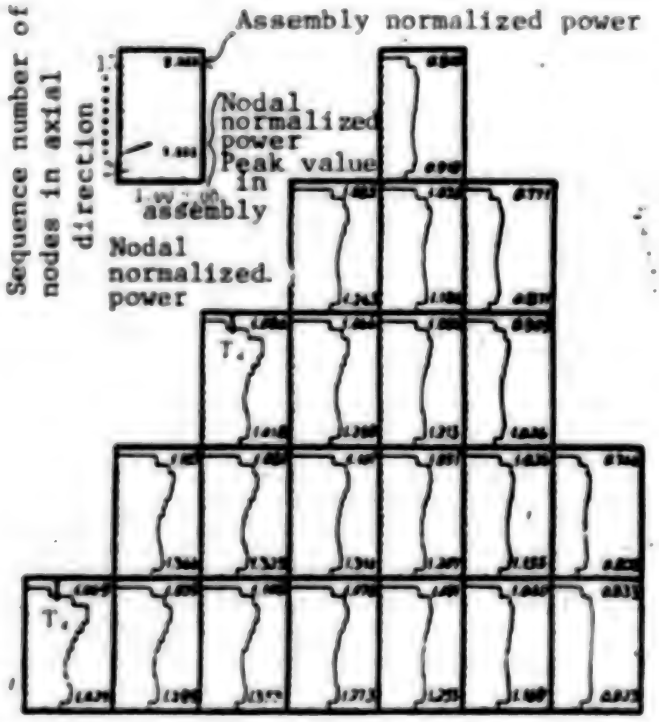

Figure 7. Nodal Normalized and Assembly Normalized Power Distribution at the Final Stage of the First Cycle

Table 2. Nodal Normalized Peak Power (F_{xyz}) and Assembly Normalized Peak Power (F_{xy})

		Burn-up without rod		Burn-up with rod	
		No feedback	Feedback	No feedback	Feedback
Initial stage	$F_{xy,z}$ direction section number, node number	1.739(9,14)	1.665(8,14)	1.943(7,14)	1.852(7,14)
	F_{xy} assembly number	1.231(14)	1.221(14)	1.214(5)	1.212(5)
Middle stage	$F_{xy,z}$ direction section number, node number	1.368(5,3)	1.348(6,3)	1.532(10,1)	1.463(10,14)
	F_{xy} assembly number	1.220(3)	1.214(3)	1.211(3)	1.197(3)
Late* stage	$F_{xy,z}$ direction section number, node number	1.249(4,5)	1.218(4,5)	1.568(13,14)	1.432(13,1)
	F_{xy} assembly number	1.104(5)	1.104(10)	1.130(10)	1.119(3)

* Since the life-times are different in the four calculations, the life time is taken to be 420 days.

As can be seen from the table and graphs that, in a given fuel assembly, the nodal normalized peak power and the assembly normalized peak power of the burn-up without rod show only slight deviation at the late stage of the feedback calculation. Although the introduction of the control rod does not appreciably affect the assembly normalized peak power, it does increase the nodal normalized peak power considerably. Also, the hottest node no longer occurs in the hottest assembly. Therefore, direct 3-D analysis must be done to locate the hottest node and the hottest assembly.

It can also be seen that, whether the burn-up is with rod or without rod, the F_{xyz} and F_{xy} without feedback are greater than those with feedback. The effect is especially pronounced for F_{xyz}. This shows that the smoothing effect of the feedback on the power distribution is mostly in the radial direction. The power anomaly is usually the largest at the initial phase of the burn-up and the smoothing effect of the feedback is therefore most important in the initial stage. Using the data in Table 2, the smoothing effect is estimated to be 5 percent. The smoothing effect can be greater in special cases when the power fluctuation is large.

3.3 Burn-up depth

Figure 8 shows the 3-D nodal burn-up distribution and the 2-D nodal burn-up distribution at the late stage of the first cycle of a burn-up with feedback and with rod. The burn-up depths of the fuel assemblies at the middle stage of the burn-up are given in Figure 6.

Although the introduction of the control rod has a large effect on the radial power distribution, a proper insertion depth and lifting speed move the peak

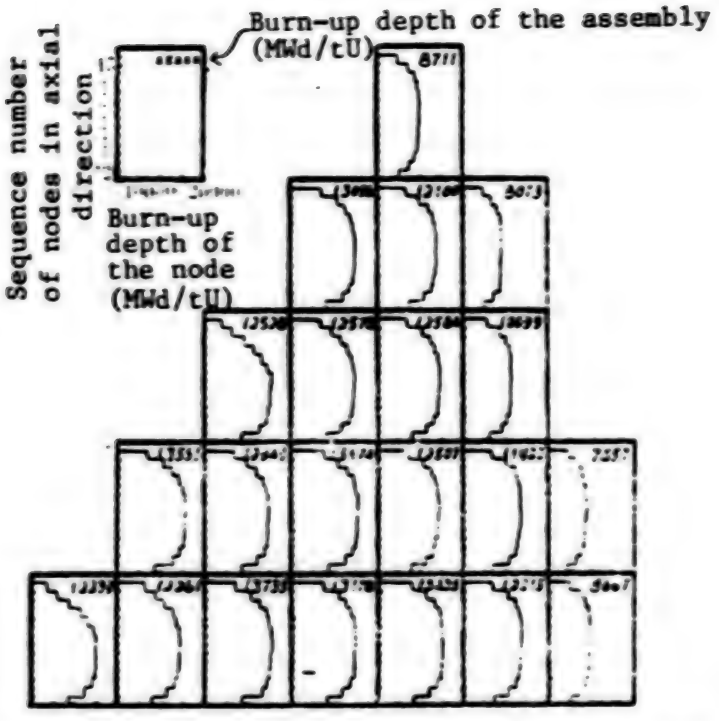

Figure 8. 3-D and 2-D Burn-up Distribution at the Late Stage of the First Cycle

power of the burn-up process from the lower part of the reactor core gradually upward and thereby smooth out the burn-up distribution of the fuel assembly in the axial direction.

The situation is naturally not so desirable in the inserted assemblies. In the calculation of the burn-up depth per fuel assembly, the difference between with rod and without rod is no doubt important. The burn-up depth is considerably less in the inserted assemblies.

Temperature feedback has no obvious effect on the late stage burn-up distribution.

3.4 Isotope loading

Figure 9 shows the consumption and regeneration of the fissionable isotope in the first cycle of the burn-up process with feedback and with rod.

Calculation results for the four different conditions show no obvious difference between with feedback and without feedback, and between with rod and without rod, for the same burn-up depth and for the entire reactor. The results of the 3-D calculation and the 2-D calculation are also consistent. Of course, the amount of isotope for a given fuel assembly depends on the burn-up history (or power history) of that particular assembly in the burn-up process, and the calculated results will naturally depend on the calculation condition, especially the presence or absence of the rod.

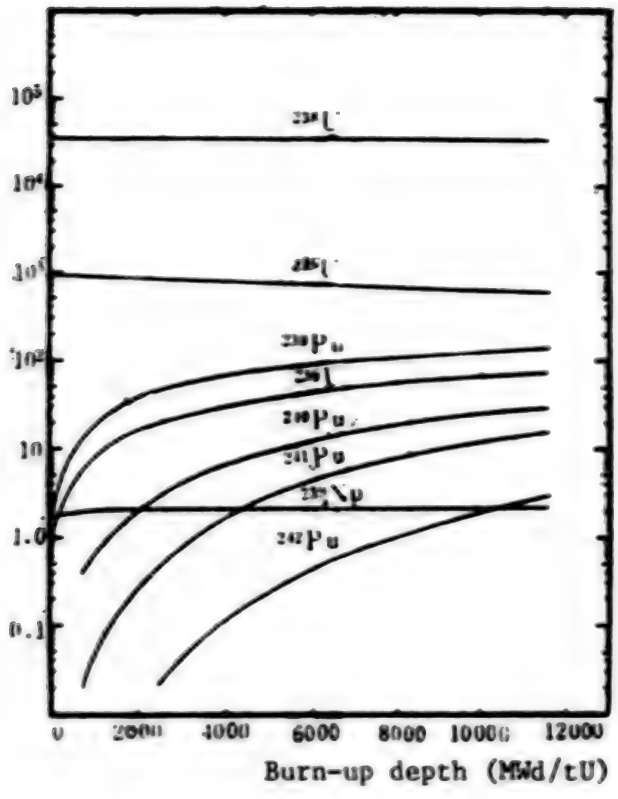

Figure 9. Consumption and Regeneration of Fissionable Isotope in the Burn-up Process

REFERENCES

1. Cheng Pingdong and Shao Yianwei: HE DONGLI GONGCHENG [NUCLEAR POWER ENGINEERING], 3 (1), 64 (1982).

2. Li Huizhu [2621 5610 3796], et al.: HE KEXUE YU GONGCHENG [CHINESE JOURNAL OF NUCLEAR SCIENCE AND ENGINEERING], 1 (1), 28 (1981)

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APPLIED SCIENCES

NEW METHOD FOR DIRECT MEASUREMENT OF EOS OF MATTERS--IMPROVEMENT OF AN EMV GAUGE

Beijing LIXUE XUEBAO [ACTA MECHANICA SINICA] in Chinese No 3, May 83 pp 298-300

[Article by Liang Yunming [2733 7189 2494], Beijing Institute of Technology]

[Text] Measurement of matter impact equation of state EOS is an important basic research task. Traditionally, it is measured by contrastive, free surface, or retardation methods all of which require a great deal of work. Measuring the EOS by these methods is indirect measurement. We have improved the electromagnetic gauge to carry out direct measurement.

The improved velocity gauge is buried in the medium to be measured and placed in a magnetic field. When the shock waves reach sensitive arm "1," the movement of "1" produces an electromotive force at both ends of the copper foil. If the direction of motion, sensitive arm and magnetic field direction are vertical, then according to Faraday's law the following can be directly derived

$$E = u \cdot L \cdot B \times 10^{-4} \text{ V}$$

in which L(mm) is the length of the sensitive arm; u(mm/μs) is the velocity of motion of the sensitive arm, and when the metallic foil is very thin it matches the medium's velocity of motion very quickly. When the shock wave reaches moving arm "2," the terminal electromotive force reacts with a jump in "2" and a linked action of "1" and "2." Thus, E_1 can be derived from the motion of "1" and u_1 can be measured; E_2 can be derived from the motion of "2" and u_2 can be measured; and shock wave velocity $\bar{D} = \frac{x_{12}}{\Delta t}$ can be derived from the time difference Δt of the jump of "1" and "2." The pressure of the medium $\bar{P} = \rho_0 \bar{D} \bar{u}$ and other state parameters can be measured from $\bar{u} = \frac{1}{2}(u_1 + u_2)$ and $\bar{D}$.

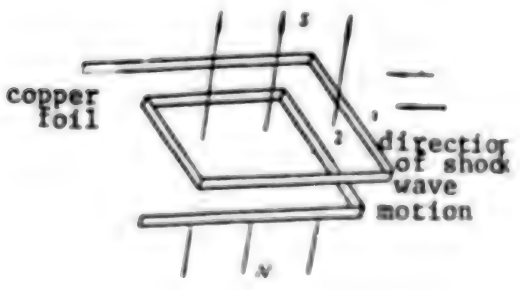
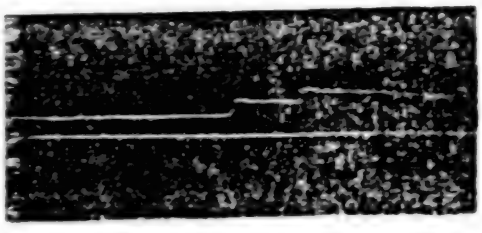


Figure 1. Diagram of the Principle of Gauges Linked Serially

The wave forms measured by gauges linked serially are illustrated in photograph 1. The test set up of the gauge and an organic glass sample are depicted in Figure 2. The overall arrangement before the explosion is illustrated in Figure 3.



Photograph 1. Test Wave Forms of Gauges Linked Serially

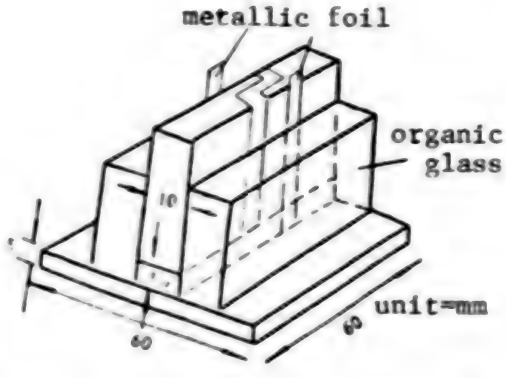


Figure 2. Diagram of Organic Glass Test Set

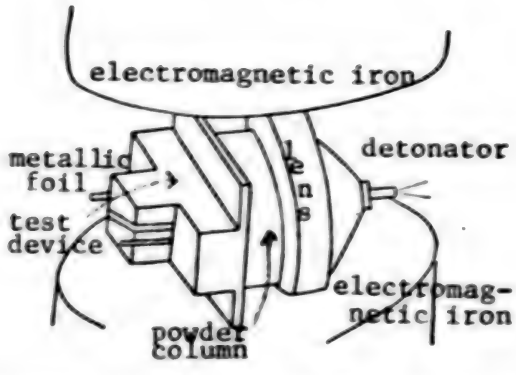


Figure 3. Diagram of Set Up Before Detonation

Using this method, though the equation of state impact pressure of an unknown medium can be measured directly, there is no need for standardization; it is clearly superior to the pressure resistance method and other methods for measuring pressure.

In spite of the fact that changing the powder load column or gauge position can change the intensity of the shock wave, many groups of $\bar{D}$ and $\bar{u}$ values can be measured. In this way, the coefficients C_0 and λ in the shock EOS of the substance measured as

$$D = C_0 + \lambda u$$

become extremely direct and simple. Our designed electromagnetic field is 2000 gauss, but in this experiment the field we used was 400-500 gauss and each test had to be measured separately.

We used two explosive charges, TNT and 8321. The shock parameters we measured for domestically manufactured organic glass plate are given in Table 1.

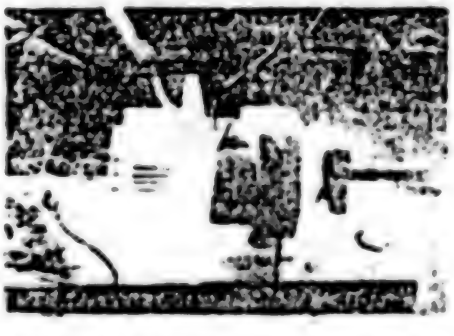
Table 1. Test Measurement Data

Sequence # / Parameter	12-5-2	11-16-1	11-20-3	11-20-1	11-20-4	11-26-2	11-20-5
$\bar{u}$	0.99	1.16	1.11	1.21	1.35	1.58	1.14
$\bar{D}$	4.73	4.94	5.03	5.51	5.64	6.36	5.62

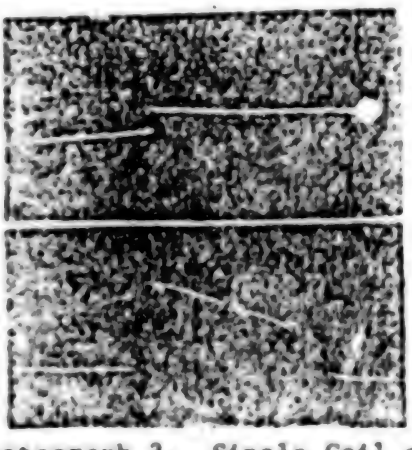
Using the method of the least squares, we obtain $C_0 = 2.21$ and $\lambda = 2.62$. The relational coefficient $r = 0.91$. For the test set up see Photograph 2.

From a comparison of the above data and the $C_0 = 2.87$, $\lambda = 1.88$ data for a domestically manufactured organic glass rod, the maximum relative error is 20 percent.

If "1" and "2" are placed on the same plane, then the gauge output will be doubled and does not require broadening the range of the plane. The experiment showed that it is also not difficult to amplify the signal by one order of magnitude. This has practical value for measuring weak shock waves. The amplification of multicoil gauges does not have any obvious impact on the progress of the signal. We used a model CD3 low inductance bridge gauge with a single core plastic lead 1 mm in diameter and 130 mm in length. Single coil value is 0.31 μH and five coil value of only 0.51 μH. The wave forms and data measured in the explosive test are shown in Photograph 3 and Table 2. The ratio of gauge coils was 1:3:5. The measurement voltage ratio was not greater than 5 percent.



Photograph 2. Test Setup (left to right: test device, powder column, lens, detonator)



Photograph 3. Single Coil and Five Coil Wave Forms

Table 2. Multicoil Gauge Test Values

Sequence	Number of coils	E(v)	u	Oscilloscope
11-26-3	1	0.51	1.07	SB-11-2
11-26-3	3	1.30	0.91	SB-11-1
11-26-3	5	2.60	1.09	OK-17

Placing the gauge on the interface of the TNT (ρ_0 = 1.50 g/cm^3) and the organic glass, the measured interface velocity was 1.93 mm/μs, calculated value 1.84 mm/μs. Relative error 5 percent.

This research is still continuing. Preliminary design a constant magnetic detector for measuring the equation of state in a variety of media (stone, soil, explosives and liquids) and for measurements in the field has already been completed. From laboratory tests it can be seen that producing a small scale gauge for measuring velocity and pressure is quite possible.

Jiang Junping [5592 0689 1627], Zhen Guangping [3914 1684 1627] and Sui Jianhui [7131 1696 6540], 1981 graduates, participated in some of the experimental work in this essay and Messrs Zhao Hengyang [6392 5899 7122], Huang Zhengping [7806 2973 1627], and Xu Gengguang [1776 2577 0342] also supported and made contributions to this work.

BIBLIOGRAPHY

1. Erickson, L.M., et al., "The Electromagnetic Velocity Gauge: Use of Multiple Gauges, Time Response and Flow Perturbations," 7th SYMPOSIUM ON DETONATION (1981).

2. Zhao Hengyang [6392 5899 7122] and Liang Yunming [2733 7189 2494], ELECTROMAGNETIC TEST RESEARCH, EXPLOSION AND SHOCK, 1 (1981).

3. Zhang Baoduo [1728 1405 6995] et al., EXPLOSIONS AND THEIR FUNCTION, National Defense Industry Publishers (1979).

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APPLIED SCIENCES

BEIJING INSTITUTE OF AERONAUTICAL ENGINEERING'S NEW WATER CHANNEL OUTLINED

Beijing GUOJI HANGKONG [INTERNATIONAL AVIATION] in Chinese No 10, 5 Oct 84 pp 5-7

[Article by Lian Qixiang [6647 0366 4382] and Huang Zheng [7806 2398]: "Beijing Institute of Aeronautical Engineering's Aerodynamic Laboratory Water Channel"]

[Text] To fill a gap in turbulence coherent structure research and new flow field display technology, the Beijing Institute of Aeronautical Engineering's aerodynamic teaching and research section in 1979 decided to build a medium sized water channel to be used in flow field display and boundary layer research, and in the same year build a water channel model 1 meter in overall length and by observing and measuring turbulence boundary layers and by working out problems of adjusting the flow in the water channel, and obtaining experience in hydrogen bubble display methods, provided data for the design of the water channel. The design of the water channel officially began in the first half of 1980 and it was built and went into use in March 1983. This is a return flow type water channel with storage tank and water purification equipment. All components are made of organic glass. The test section dimensions are 0.4 m x 0.4 m x 6.8 m, maximum flow speed is 0.15 m/sec, the same as water channels or water tunnels used for flow field display by other countries.

Features of water channel design

Since the water flows from the return flow pipe into a tranquil section, and where it enters the tranquil section, the flow turns 90° and the surface suddenly becomes wider by tens of times, the flow is very turbulent but using an adjustment net cannot even out the flow, thus a piece of foamed plastic 5 cm thick was fixed between two layers of nylon fabric in the tranquil section and after the water flowed through the foamed plastic, the water head dropped about 2 cm; the water head in the test section was about 1 mm and in the tranquil section the water head was less than 0.01 mm which shows that the originally turbulent flow after being completely filtered by going through the foamed plastic and the flow speed once again could be transformed by pressure.

The flow speed of the water channel is low, and although the absolute value of the flow speed unevenness is small, the relative unevenness is large thus a large contraction ratio is used to achieve a good flow field. Initially, a

weiduoxinsiji [4850 1122 6580 2448 1015] formula was used to design the contraction curve, but after calculations it was discovered that because the wall surface curvature change was too great, too fast a contraction before the contraction section, made it possible for a reverse pressure area to appear in the later section which meant that this formula was not suited to the design of a large contraction ratio curve. For this reason, in accordance with the principle of making the water flow acceleration change zero at the two ends of the contraction section and at the maximum in the central section, continuously, a contraction curve with a ratio of 16 was designed.

When debugging, it was discovered that the wave motion on the water surface in the channel was very great. There were two wave sources: One was the tranquil section inlet as described above, caused by sudden turn in water flow and the sudden expansion of the area, and after going through the foamed plastic and the adjustment net this wave motion still was transmitted to the test section and severely affected testing. To correct this, where the return flow tube connected to the tranquil section inlet a cylindrical bag made of nylon was attached and when the water from the return flow tube had all flowed into the bag and penetrated the bag's micropores, it was basically even. The second was at the water channel outlet, and was created because in the original design the tube diameter was small, thus flow speed was high, and the air drawn in collected in bubbles which floated to the water surface and burst. For this reason, the tube diameter at the outlet was enlarged and an air vent was installed at the corner which basically resolved the problem.

The water channel was initially driven directly by a centrifugal water pump. The centrifugal water pump pressure head was 20 m, much greater than the overall loss of the water channel return flow process and the excess water head was not utilized. In 1982 a nozzle was designed and installed which used the high-pressure water head of the centrifugal pump force to drive the return flow water. Using two water pumps and one nozzle the volume of flow of the original seven water pumps could be achieved which greatly saved on operating expenses.

Water channel flow field characteristics

Since the average flow speed of a water channel used for flow field display is low, regulating the flow is very difficult. As was mentioned above, the water head in the test section was not over 1 mm and in the tranquil section it was still less than 0.01 mm. Tiny external disturbances or relative unevenness created by differences in temperature between the water and the wall can be fairly large. For example, one water droplet which is 0.4°C higher than the temperature of the surrounding water can gain in buoyancy an increase in flow speed of 0.2 cm/sec within 1 second. Thus, although foamed plastic and multiple flow adjustment nets are used and the contraction ratio is as high as 16, the evenness of the flow field still is 2 percent, and it has not yet reached the level of the ordinary wind tunnel.

Large-scale tests conducted in this water channel show that the quality of flow field display is about the same as similar tests internationally, and the test results have their own uniquenesses.

Test methods

The hydrogen bubble tracer method is mainly used for flow field display and boundary layer research. A platinum wire 25 microns in diameter is placed in the water channel and connected with the negative pole of an electrical source, the positive pole is placed far downstream where the flow field will not be disturbed. After introduction of a square wave pulse voltage hydrogen is produced on the negative pole by the electrolysis of the water. Since a pulse voltage is used, the hydrogen bubbles produced by the electrolysis of the water can be made to appear at set time intervals and form many ripples along with movement of the water so that flow time can be recorded. This is called the hydrogen bubble time line. Figure 2 is a display of an even flow field's hydrogen bubble time line. A simple time line is not sufficient to show flow direction, which generally should make "symbols" at the platinum wire so that an indicator is attached to the hydrogen bubble time line forming a hydrogen bubble time pulse line, see Figures 4 and 5. The hydrogen bubble time pulse line can provide pretty complete information, giving both the time coordinates and indicating the specific gaseous particles.

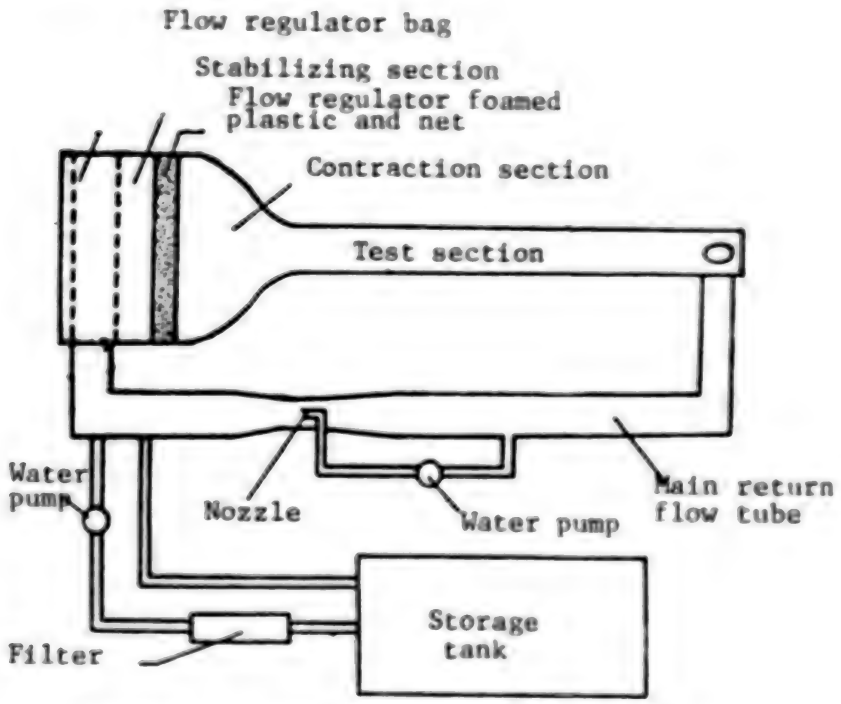

Figure 1. Arrangement of Water Channel

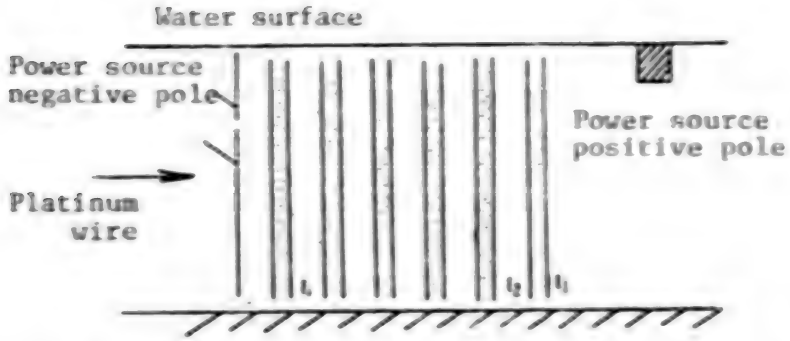

Figure 2. Diagram of Even Flow Field Hydrogen Bubble Time Line Display in Water Channel

Figure 3. Display of an Even Flow Field's Hydrogen Bubble Time Line

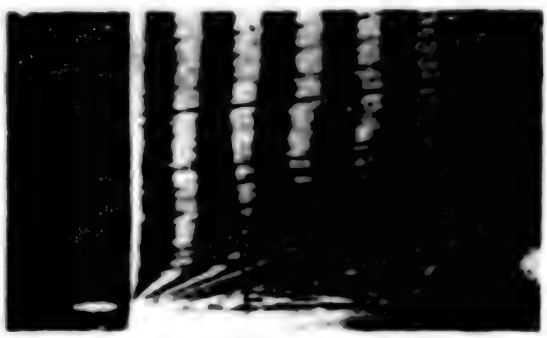

Figure 4.

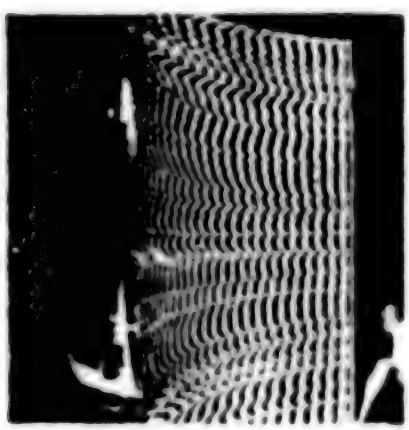

Figure 5. Flow Line Direction and Speed Distribution in Front of Umbrella

Water channel functions

Since the water channel went into use in 1981 it has been used to carry out research work on a great many fundamental tests. Three of these aspects are treated briefly below:

1. Research on turbulent boundary layer coherent structures. Coherent structures are a type of large size structure in turbulence. They have definite laws and frequently appear over and over again, but they have no fixed period and the forms in which they appear each time are not completely identical. After turbulent coherent structures were discovered in the sixties, our understanding of turbulence mechanisms has advanced greatly. Figure 3 is the hydrogen bubble time line of the bottom layer structure of a reverse pressure area boundary layer. One can see that the bottom layer of the turbulent boundary layer has areas of constantly changing high and low speed; where the hydrogen bubble time line is sparse (i.e., high flow speed area) it is called fast stripes and where the hydrogen bubble time line is dense (i.e., low flow speed area) it is called slow stripes. From tests it has been observed that on the edges of the slow stripes on one side there is a slow transition to the fast stripe and on the other side is a sudden transition so that disarrangement appears and there is drawn out a streak which rises, oscillates and bursts, providing energy for the turbulence. In tests one can see lateral vortices and flow direction vortices in the layer. Tests on turbulence boundary layers in reverse pressure area show that in reverse pressure area slow stripes become wider and sometimes even form intermittent back flow stripes; the burst period becomes larger; the size of the lateral vortices and flow direction vortices become larger and the lateral vortices become more numerous; the diameter of the lateral vortices and the flow direction vortices can reach two-thirds the thickness of the transient boundary layer, see Figure 4, nearly equal to the thickness of the boundary layer and in addition, the induced speed can make the flow speed of the transient portion outside the near wall greater than flow speed of the free flow outside the boundary layer. If the creation and development of these lateral vortices can be controlled, then there is a chance that the isolation of the turbulent boundary layer can be delayed.

2. Display of the parachute flow field. The arodynamic problem of the parachute is a problem of complex isolation flow and flow around a soft permeable material. Using hard models of parachutes, tests were conducted in the water channel, the flow speed distribution in front of, and behind, the umbrella and the frequency of the eddies produced by the skirt of the umbrella were measured to provide data for designing new parachute types. Figure 5 clearly shows the flow line direction and speed distribution in front of the umbrella. Because it was obstructed by the umbrella, near the central portion of the umbrella, the hydrogen bubble time line is dense and the reduction in speed is the greatest, but the flow line outside the center curves outward and there is no reduction in speed, but near the edge the flow accelerates. If a general measurement method is used, it will take a fairly long time to obtain such distribution diagrams. Therefore, when developing new parachutes using the water channel to conduct hydrogen bubble tests for preliminary model selection makes it possible to avoid some unnecessary model release testing in a vacuum or in a wind tunnel.

3. Research on starting eddies. Researching flow fields at start up has important significance for many nonsteady moving bodies (such as the influence of projectile launch, release, parachutes, missile launch pads, and wind gusts on aircraft and buildings). The flow field of blunt bodies in accelerating/decreasing flow speed is very different from the flow field in steady flow. The wake of two dimensional plates, discs, projectiles and parachutes tested in the water channel at accelerated speed flow clearly show the development process of start-up eddies from small to large and then to fracture. Figure 6 is the hydrogen bubble time line display of the startup eddies behind a two-dimensional plate. One can clearly see a pair of startup eddies arranged symmetrically on the back of the plate, from small (Figure 6 (a)) to large (Figure 6 (b)). When the eddy is at its largest, the backflow speed is at its greatest, which can reach about 3.6 times that of the steady state. The position, size, changes of the backflow speed in the startup process, and the width of the wake area can be measured to provide reference materials for engineering design. From Figure 6 (b) one can also see a series of small eddies along the edge of the startup eddy which shows the physical basis for calculating the dispersion eddy model of this type of isolated eddy.

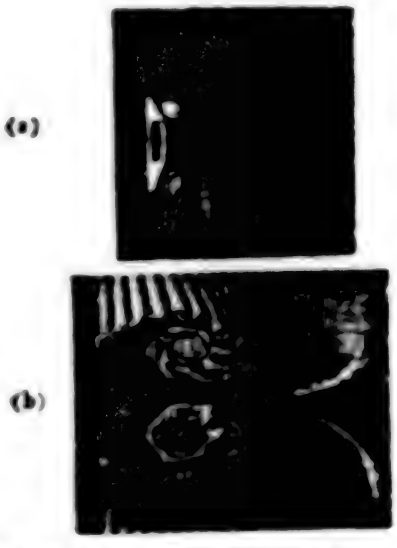

Figure 6. Hydrogen Bubble Time Line Display of the Startup Eddies Behind a Two-dimensional Plate

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CSO: 4008/122

APPLIED SCIENCES

CARDC'S LOW-SPEED WIND TUNNEL DESCRIBED

Beijing GUOJI HANGKONG [INTERNATIONAL AVIATION] in Chinese No 10, 5 Oct 84 pp 2-4

[Article by Wang Maoxun [3769 2021 8113] and Pan Ruikang [3382 3843 1660], China Aerodynamic Research and Development Center: "The CARDC 8 m x 6 m Low-speed Wind Tunnel"]

[Text] The China Aerodynamic Research and Development Center (CARDC)'s 8 m x 6 m low-speed wind tunnel is a large-scale dual test section wind tunnel designed and built by China. It is mainly used for testing the aerodynamic characteristics of airplanes and other aircraft; testing surface wind load of guided missiles and spacecraft; testing the major angle of attack of aircraft and guided missiles; testing large-scale models; testing the aerodynamics of helicopters and vertical and short-distance take-off and landing aircraft; and testing industrial aerodynamic surfaces (such as buildings, bridges, windmills and vehicles).

Dynamic debugging of the wind tunnel was completed in 1978 after which flow field calibration and standard model testing was carried out. After 5 years of operation and model aerodynamic testing the conventional testing and measurement system was automated and after passing national appraisal at the end of 1983 it was formally delivered for use.

Introduction to the Wind Tunnel

The 8 m x 6 m wind tunnel is a large-scale, low-speed open-type wind tunnel with dual in-line closed test sections. Overall length is 237 m, maximum width is 40 m, maximum height is 20.5 m, and it is made up of the intake apparatus, stabilizing section, first constriction section, first test section, second construction section, second test section, first diffusion section, fan section, second diffusion section, and air exit (see Figure 1). The ceiling of each test section has movable gates, in the center of the floor there is a turntable that can rotate 360°, and in the sidewalls and ceiling there are many observation windows. Table 1 gives the important performance parameters of the two test sections. The first test section is primarily for low-speed tests of helicopters and V/STOL aircraft, and research on testing industrial aerodynamic surfaces. For this reason, when the wind tunnel was designed, the demands for quality of flow field were low, they just had to be able to satisfy

test demands. The second test section is the main work section of this wind tunnel; the quality of its flow field achieved design norms and the unified stipulated norms for low-speed wind tunnels nationwide, see Table 2. The precision of the test results using domestic low-speed wind tunnel uniform force measurement standard model to conduct an evaluative test in the second test section are given in Table 3, test ram pressure was 287 kg/m^2, test Reynolds number was 3.9×10^6. Table 4 gives the precision of measurements of lateral and axial force with a standard DBM-01 model and the measurements of aerodynamic characteristics.

Table 1. Important Performance Parameters of the Two Test Sections

	First test section	Second test section
W x H x L	12 m x 16 m x 25 m	8 m x 6 m x 15 m
Maximum air speed empty	25 m/sec	100 m/sec
Minimum stable air speed	1.75 m/sec	7 m/sec
Model test air speed	5-21 m/sec	20-85 m/sec
Model area length	x < 16 m	3 m < x < 12 m

Table 2. Flow Field Performance of Section Test Section

Air flow stability		< 0.5
Axial static pressure gradient dCp/dx (1/m)	no floor	- 0.0003
	with floor	- 0.003
Dynamic pressure field		$\mu \leq$ 0.5 percent
Direction field		d (β) $\leq$ 0.5°
Turbulence number		ε = 0.1 percent
Temperature rise		- 2°C $\leq \Delta t <$ 0°C

Table 3. DBM-01 Standard Model Small Angle Force Measurement Precision

Root-mean-square deviation	σC_L	σC_D	σC_M	σC_Y	σC_l	σC_n
8 m x 6 m wind tunnel test values	0.001	0.0005	0.0003	0.0005	0.0003	0.0002

Table 4. DBM-01 Standard Model Overall Aerodynamic Characteristics Data Comparison

	C_{La}	α°_{o}	C_{D_o}	$C_{m_{cL}}$	Cm_o	$Cy\beta$	$Cn\beta$	$C_{l\beta}$
8 m x 6 m wind tunnel value	0.055	-0.2	0.011	-0.064	-0.005	-0.0098	-0.0042	-0.00105
U.S. 12 ft. Ames wind tunnel value	0.055	-0.2	0.011	0.064	-0.006	-0.0104	-0.0044	-0.0011

The fan housing is situated between the first and second diffusion sections and is made up of three round channels arranged in a triangular fashion. Three fans are inside it, each powered by a dc motor (2,600 kW each), see Figure 2. The motors are supplied by a high-power thyristor feed motor with maximum of 480 rpm. The diameter of each fan is 7 m and each is made up of 15 glass blades. Highly precise stable speed control systems and stable speed pressure automatic control systems regulate the motor revolutions to guarantee stable wind speed in the test section.

The wind tunnel is equipped with a conventional six-component balance made up of force measurement component, model support, and machinery for changing the attitude angle. The force measurement balances uses a strain balance component with box, rod, ring and composite type balance components of different capacities and is used for conventional and special tests.

The wind tunnel has a variety of scanning valves and pressure sensors of various capacities.

There is also a compressed air system for jet testing.

The control room has the controls for the dynamic control system, the model atitude angle control system, the compressed air regulation system of the jet tests, and the hydraulic control system for opening and closing the wind tunnel gates and raising and lowering the test platform.

The wind tunnel is equipped with a computer and low- and medium-speed measuring devices, and various computer peripherals which form an automated data collection and processing system. Real-time processing of test data provides test results and curves.

In the more than 5 years' time since 1978, this wind tunnel has been used for many tests, including strategic and tactical guided missiles, flight vehicles, and aerodynamic tests for civilian industries. At the same time, research on new test technology has been actively carried out including tests on large angle of attack, fluid state display technology, static and dynamic tests on various kinds of parachutes, and automobile wind tunnel tests, all of which has constantly complemented and improved this test equipment.

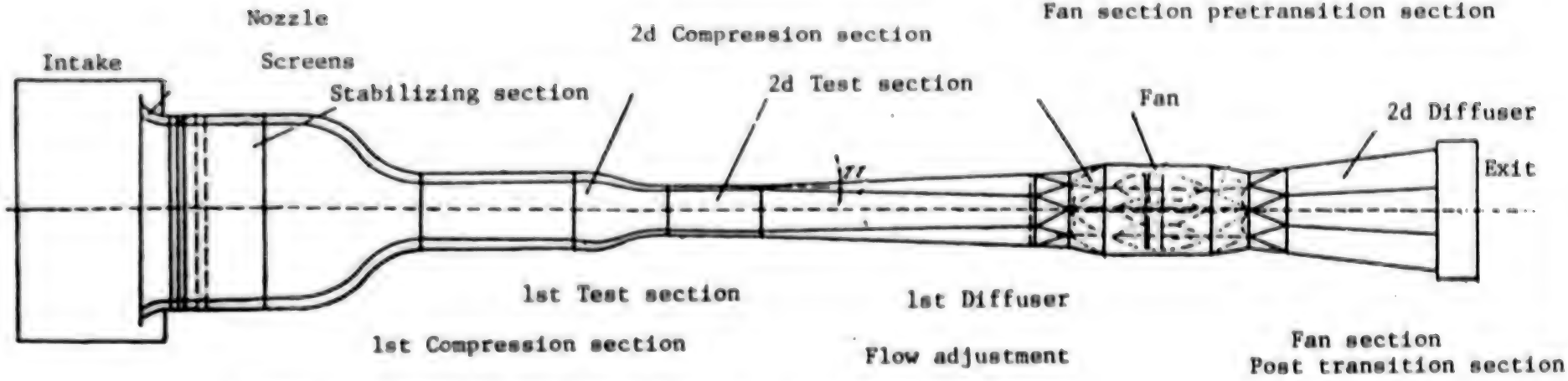


Figure 1. Layout of the CARDC 8 m x 6 m Low-speed Wind Tunnel

Figure 2. The Configuration of the Tunnel

Figures 3, 4 and 5 show the simulation ability of the wind tunnel in aircraft test Reynolds number, helicopter progressive ratio, and blade load. The superior features of using this wind tunnel for testing are: 1) a large-scale model can be used which increases the test Reynolds number and can simulate more accurately the aerodynamic shape, surface protuberances, and cracks in the rudder surface of aircraft. 2) Test Reynolds numbers are large. 3) Test speed range is broad.

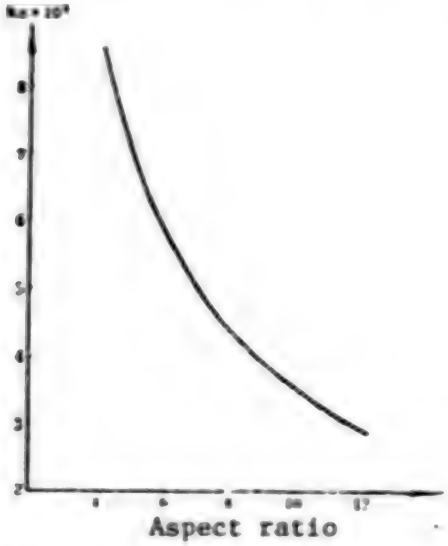


Figure 3. Reynolds Test Number Achieved by Aircraft of Various Aspect Ratios at 85 m/sec

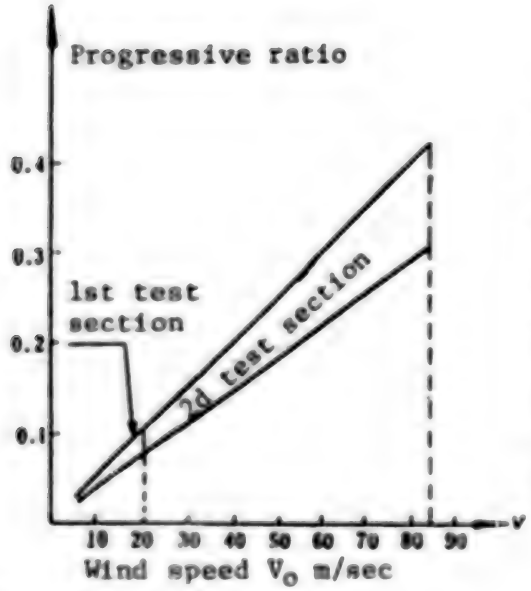


Figure 4. Progressive Ratio Simulation Ability

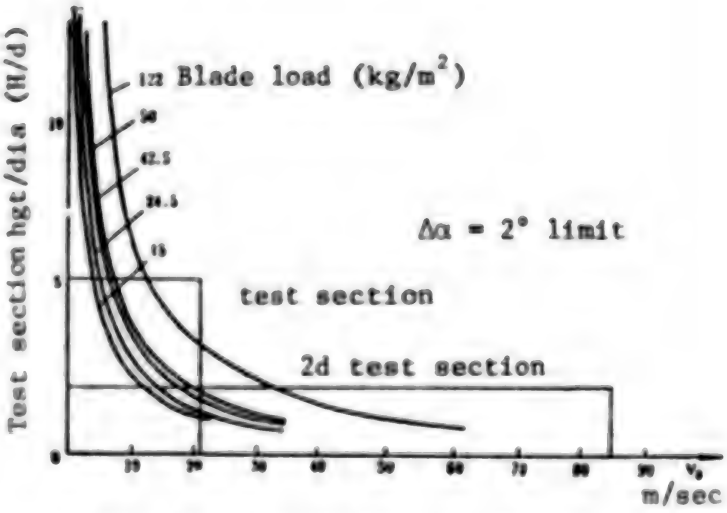


Figure 5. Simulation Ability for Blade Load

Figure 6 shows the DBM-01 model carrying out surface effect tests in this wind tunnel.

The key to large angle of attack test technology for aircraft lies in resolving the problems of correcting for support interference and separator walls. For small wind tunnels, this is relatively difficult, but in an 8 m x 6 m wind tunnel, a relatively large Reynolds number can be guaranteed and interference of the tunnel walls can be reduced so that satisfactory test results can be obtained. At the present, this wind tunnel uses tail controlled large angle of attack test devices which can make the angle of attack as large as 110°.

Carrying out small-scale model tests in a large wind tunnel is one important way of studying tunnel wall interference. Comparison of test results of a model in a 3 m wind tunnel and in an 8 m x 6 m wind tunnel show that the slope of the lift force line obtained in a small wind tunnel tends to be larger. Also, tail controlled pressure tests conducted in an 8 m x 6 m wind tunnel play a beneficial role in the accuracy of the pressure test results.

In recent years, the 8 m x 6 m wind tunnel has been used for a great many tests on wind force machines, structures, towers, automobiles, long range radar antennas, sports equipment, and high tension lines. In particular, good results have been obtained in tests on large; medium; and small-scale vehicles and a composite strain balance has been provided especially for automobile tests. Automotive industry departments and designers have already begun to make automobile wind tunnel tests an important part of new car design and model determination. Figure 7 shows a wind tunnel test of a Shanghai brand sedan, and inside the front cover shows a wind tunnel test of a television tower.

Figure 6.

The CARDC is still improving and perfecting the 8 m x 6 m low-speed wind tunnel so that this wind tunnel will have higher test precision and efficiency.

8226
CSO: 4008/122

APPLIED SCIENCES

ANTARCTIC EXPEDITION GATHERS DEEP WATER SAMPLES

OW221704 Beijing XINHUA in English 1635 GMT 22 Jan 85

["Chinese Expedition Gathers Samples More Than 1,000 Meters Deep in Antarctic Ocean in Zhu Youdi"--XINHUA headline]

[Text] Aboard the S. S. Xiangyanghong 10, Antarctic Ocean, 21 Jan (XINHUA)--The Chinese Antarctic expedition team has completed surveys in five oceanographic stations in the Antarctic Ocean and gathered data and samples from the ocean's bathypelagic zone more than a kilometer below sea level.

The Chinese team sailed from King George Island to the Antarctic Ocean on 19 January.

Most of the five oceanographic stations are located in the bathypelagic zone, which has complicated submarine topography and a water depth of more than 1,000 meters.

The samples gathered by the Chinese expedition team from the bathypelagic zone include micro-biological and geochemical specimens, deep-sea floor sediment, rocks, and benthos.

Meanwhile, the expedition also recorded the temperature, salinity, depth, acidity and alkalinity of waters around the five oceanographic stations, gaining data valuable for analyzing the water and the current, as well as the ecological environment for krill, a small shrimp-like crustacean in the Antarctic Ocean.

CSO: 4010/68

APPLIED SCIENCES

PRC TEAM BRAVES ANTARCTIC STORM, BUILDS HOUSE

OW111550 Beijing XINHUA in English 1450 GMT 11 Jan 85

['Chinese Expedition Team Builds First House in Antarctic (by Zha Youdi)"--XINHUA headline]

[Text] South Shetland Islands, 10 Jan (XINHUA)--The Chinese Antarctic expedition team, braving a storm during the past six days, has built the first frame house of its observation station on the Fields Peninsula, King George Island.

The storm (with a high of force 11 wind on the Beaufort scale) began on 4 January, due to the effects of an Antarctic cyclone. Along with high tide, huge waves and snow, the storm disrupted the unloading and ferrying of materials for the construction of the observation station.

However, the Chinese expedition team members and seamen at "The Great Wall" station, united as one and braving the storm, have repaired the temporary quay and re-erected their tents. With the materials that have arrived earlier, they have built a wooden structure power house and the power generating unit is now operational.

Meanwhile, precautions were taken. The Chinese S. S. Xiangyanghong 10 and J121 rescue ship left their anchorage near King George Island and sailed against the wind to a safer area this evening.

CSO: 4010/68

APPLIED SCIENCES

BRIEFS

NEW TELEVISION--In 1985, a new type of 14-inch black-and-white television will go on sale in Shanghai. This new type of TV set will contain very large integrated circuits with thousands of circuit components. [Text] [Shanghai City Service in Mandarin 1100 GMT 28 Dec 84 OW]

SERIAL LOGIC CIRCUIT PRODUCTS--Beijing, 23 Dec (XINHUA)--According to the office of the Leading Group for the Development of Electronic Industry under the State Council, the 26 high-speed CMOS74HC serial logic circuit products trial-produced by the Shanghai Metallurgical Institute of the Chinese Academy of Sciences, the Shanghai Radio Plant No 14, and the Shanghai Radio Elements Plant No 5, passed appraisal in Shanghai recently. This serial circuit can be extensively applied to digital communications, computers, and industrial automatic control, and home appliances. [Beijing XINHUA Domestic Service in Chinese 0037 GMT 23 Dec 84 OW]

MICROCOMPUTERIZED MEDICATION DISPENSER--Wuhan, 23 Dec (XINHUA)--China has successfully produced a microcomputer to monitor rational clinical medication. This device passed appraisal in Wuhan on 20 December 1984 under the sponsorship of the PLA General Logistics Department. This device is easily operable, portable, and inexpensive. It uses the Chinese language to tell the names of medication and disease and the physical state of a patient and warn with sound and light in case of contraindication in terms of medication, dosage, and injections. It is also quite original and advanced compared with foreign devices. [Beijing XINHUA Domestic Service in Chinese 23 Dec 84]

CSO: 4008/185

LIFE SCIENCES

PRC PUBLIC HEALTH MINISTER ON MEDICAL SERVICES

OW201254 Beijing XINHUA in English 1223 GMT 20 Jan 85

[Text] Beijing, 20 Jan (XINHUA)--China added 63,000 hospital beds last year and built more than 50 maternity and child care centers, Minister of Public Health Cui Yueli said here today.

In addition, more than 200,000 patients in need of hospitalization were treated at their homes, he said.

He told a national conference of heads of public health bureaus open here today that the achievements in preventive medicine, controlling of endemic and infectious diseases were also encouraging.

Over the past year, he said, various localities, collectives and even individuals all pooled funds to build hospitals. In Guangzhou, people pooled more than 100,000 yuan to build a hospital with more than 70 beds, exclusively for elderlies. In Beijing, a township in Shunyi County raised 1.5 million yuan to build a 130-bed hospital for treating bone diseases and injuries.

By the end of 1984, the number of hospitals of traditional Chinese medicine at the county level and above grew to 1,020. In addition, ten centers for training doctors of traditional Chinese medicine were set up and the number of traditional Chinese medicine research institutes at the prefectural and city levels came to 48.

The incidence of acute infectious diseases dropped by 20 percent from 1983 and filariasis was basically eliminated in Guizhou Province and 496 counties and cities, which account for 57.4 percent of the filariasis infested areas in the whole country.

The incidence of malaria in Jiangsu, Shandong, Henan, Anhui and Hubei Provinces dropped by 30 percent and the incidence of tuberculosis has dropped at an average annual rate of about 6 percent since 1980.

No incidence of the plague was reported last year. Endemic goiter was brought under control in Shaanxi, Heilongjiang, Tianjin and five other provinces and cities. Last year, 16 counties and cities reported to have eliminated snail fever.

In 1984, the country set up more than 50 maternity and child care centers, which brought down sharply the incidence of child dietary anemia and rickets and the morality rate of pregnant women to about five per ten thousand. Over 90 percent of babies were delivered by the new method instead of the old traditional midwifery.

The public health minister said that progress was also made in medical research and education. In the past year, China set up six managerial personnel training centers and 97 centers for advanced studies and quite a number of correspondence and evening schools. Recuperative medicine is spreading throughout the country.

The past year also saw stepped-up cooperation with foreign countries, Cui Yueli said. The ministry sent ten delegations abroad and received eight foreign delegations. In addition, more than 12,000 medical personnel were sent abroad to study or investigate or attend international conferences. More than 2,000 foreign specialists were invited to China on lecture tours.

The China-Japan hospital with an investment of 13 million U.S. dollars coming from Japan was completed and the bio-medicine training center with aid from Denmark also began. With aid from the United Nations, China also set up demonstrative counties for maternity and child care, child first-aid training centers and cold chains for delivering vaccines.

China has 40 medical teams, about 1,200 medical personnel, working abroad.

CSO. 4010/66

LIFE SCIENCES

HEALTH MINISTER URGES REFORM IN MEDICAL FIELD

OW201834 Beijing XINHUA in English 1633 GMT 20 Jan 85

[Text] Beijing, 20 Jan (XINHUA)--Cui Yueli, minister of public health, today stressed the expansion of the decision-making rights of all the state-owned hospitals and medical institutes, and the reform of medical management including personnel and wage systems.

In his annual work report at a meeting attended by officials in charge of provincial medical work which opened here today, Cui said that a reform of the present wage system would begin in July in the light of the principle of distribution according to work, so as to better combine the remuneration of medical workers with their responsibilities and results.

As for the readjustment of medical charge, Cui explained that it would continue to be reasonable and that the readjustment was merely aimed at improving the hospitals' facilities and enabling them better to serve the patients. The charges might vary with different hospitals and doctors.

Hospital beds would be greatly increased by expanding the existing hospitals and medical units. The state would invest more in medical services and would encourage collectives and individuals to collect money to set up hospitals.

The ministry would allow some medical workers in state-owned hospitals to leave their posts and engage themselves in collective and individual medical practice. Qualified idle and retired practitioners would be encouraged to run clinics while those working in state-owned hospitals might practice in their spare-time. All this was aimed at rendering more and better medical service to the people, he explained.

Higher pay and better living conditions would be given to those doctors who were willing to serve for certain years in rural, border or remote areas where conditions were harder. While preferential treatment would be given to their children in study and employment.

Cui said that medical colleges would enroll more students and more correspondence and night schools would be set up to strengthen medical education.

He said research work would focus on applied medicine to better prevent and cure diseases. Medical research institutes would be allowed to bid for research results, set up research foundations and make contracts with research workers. Collectives and individuals would also be encouraged to run research units.

CSO: 4010/66

LIFE SCIENCES

CUI YUELI DISCUSSES CHANGES IN HEALTH SYSTEM

HK220300 Beijing CHINA DAILY in English 22 Jan 85 p 1

[By staff reporter Chen Guangfeng]

[Text] A program to invigorate the country's medical system has been drawn up by the Ministry of Public Health.

All medical institutions above county level will undergo reform this year, Health Minister Cui Yueli announced yesterday.

The program should be completed in the three to five years and will give more freedom to state medical institutions, adjust medical expenses, accumulate funds for public health, restructure medical study and research systems and expand medical exchanges with foreign countries.

"We are aiming to add vigour and vitality to our medical establishments, especially those in urban areas" the minister said at the opening of a national medical conference in Beijing.

"We hope to raise the efficiency of our medical establishments, so that they can serve the people better and improve their own economic status," Cui said.

All state-owned medical establishments are to be given greater freedom in employing workers, using their own funds and adopting management methods.

Hospital presidents will be authorized to employ, dismiss, reward and punish workers, and some state-owned medical establishments at grass-root levels can be contracted to individuals so long as their ownership does not change.

Expenses for medical treatment will be adjusted in a bid to curtail the serious losses suffered by medical establishments. The minister did not elaborate but said medical establishments should be able to operate with their own funds.

He said that charges should be linked to the quality of the services.

Services such as preventive inoculations, maternity and child care, family planning services, health checkups, medicine examination and supervision, and antiepidemic services will no longer be free. Small charges will be made in future.

The ministry will also take a number of measures to improve the country's public health, including encouraging collectives and individuals to set up hospitals and drugstores, allowing medical workers to provide after-work services, expanding exchanges with foreign countries, stepping up efforts in medical research, and training large number of medical professionals.

Cui expressed satisfaction with his ministry's work last year, saying its achievements were "extraordinary" in developing traditional Chinese medicine, disease prevention, health protection, pharmaceutical management and medical exchanges with foreign countries, especially Third World countries.

By the end of last year, Cui said, the number of colleges of traditional Chinese medicine above county level grew to 1,020. Traditional Chinese medicine training centres now number 10, and traditional Chinese medicine research institutes above prefecture and city level now total 43.

The number of tuberculosis patients has been declining at an average annual rate of 6 percent since 1980, food poisoning cases dropped by 44 percent last year, the death rate during pregnancy and childbirth was brought down to about five per 10,000, and 40 medical teams with a total staff of nearly 1,230 were sent to work abroad.

CSO: 4010/66

LIFE SCIENCES

HEBEI PROVINCE LEADER IN MEDICAL SERVICES

OW211650 Beijing XINHUA in English 1638 GMT 21 Jan 85

[Text] Beijing, 21 Jan (XINHUA)--Surgeon Liang Donghai runs a hospital in his home in Longyao County, Hebei Province, and insists that he will not charge until the patient is cured.

After service in an army hospital where he learned surgery, Liang collected money two years ago and opened his small hospital with 10 beds, specializing in anal fistula conditions as well as some common diseases. He is one of thousands of private practicioners who have appeared recently in this north China province.

As one of the steps taken by the province to improve medical service, nearly 4,000 doctors like Liang were encouraged to start their private practices after strict examinations, said Fu Dawei, head of the provincial public health department, during a national meeting for provincial medical officials now in progress here.

Fu said that, as in the whole country, private practice was looked upon as illegal and was forbidden in the province in the past, but the few state-run hospitals and medical services could barely cater to the needs of the numerous patients.

To put an end to this situation, steps were taken including permission for private practice by unemployed and retired medical workers.

Besides, doctors were encouraged to engage in medical undertakings in areas where conditions were harder, but they were allowed to return to their formal work at any time.

According to incomplete statistics, individuals collected money and set up 35 medical services in 11 areas and cities of the province, and another five hospitals were built by rural enterprises and technically equipped by state-owned hospitals. Nearly 1,000 medical workers were sent by big hospitals to some 400 service centers in rural areas.

Helped by retired cadres, Li Jiantang, a veteran doctor of traditional Chinese medicine, collected 15,000 yuan for his 24-hour hospital in Feixiang County.

Another example is the 25 newly-opened clinics which handle half of the total patients in the Shanhaiguan District of Qinhuangdao City last year.

Fu said that the quality of service has improved as well in many big hospitals, as the pay of medical workers is now closely linked with the quotas, skills and responsibilities of their work. Many hospital staff worker under contract.

The doctors' bonuses are affected if they show any negligence, quarrel with patients or otherwise show themselves unprofessional.

Besides, more than 54,300 patients got regular medical treatment at home in 11 cities and prefectures last year, Fu said. This figure was five to 10 percent of the total number of hospital inpatients.

Medical officials attending the five-day meeting here appraised the work done by Hebei in this field as a model for future medical reforms throughout the whole of China. This opinion was listed in an annual work report presented to the conference by Minister of Public Health Cui Yueli yesterday.

CSO: 4010/66

LIFE SCIENCES

PRC RED CROSS SOCIETY MARKS PROGRESS, MEMBERSHIP

OW241535 Beijing XINHUA in English 1450 GMT 24 Jan 85

[Text] Beijing, 24 Jan (XINHUA)--The Red Cross Society of China now has a membership of 1.4 million, according to its vice president, Yang Chun.

At a national meeting of officials in charge of provincial health work, which closed here today, Yang said that the society had established branches in 26 of China's 28 provinces, municipalities and autonomous regions (Taiwan is not included).

These offices offer welfare for the disabled, check-up service for students, and keep-fit activities for the aged, as well as running clinics and convalescent homes.

In recent years, she said, the society has updated medical, rescue and blood transfusion services with imported techniques and equipment.

A blood transfusion bag project and expansion of the central blood bank in Tianjin, assisted by the Australian Government, will be completed this year.

The National Red Cross Training Center, with a floor space of 4,000 square meters, is under construction with the help of the International Federation of the Red Cross and Red Crescent Societies and organizations of Sweden, Australia, Japan and Tunisia.

The Chinese Society was founded in 1904 and reorganized in 1950.

CSO: 4010/66

LIFE SCIENCES

CELL LINES GROWN IN CHINA SINCE 1949

Shanghai XIBAO SHENGWUXUE ZAZHI [CHINESE JOURNAL OF CELL BIOLOGY] in Chinese
No 3, Sep 84 pp 141-142

[Text] I. Human Malignant Pleural Mesothelioma Cell Line SMC-1

This stock was drawn from the dextral panpleurectomy and panpneumonectomy specimen of a male patient with malignant pleural mesothelioma. It utilizes a long-term generative cell line established by the stationary tissue-mass culture method.

This line of cells takes on pleomorphic and distinctly overlapping growth features. The doubling time of the cell colony is approximately 32 hours, the highest fissioning index is 4.6-5.0 percent and the chromosomal mode is 60-70. Xenogenic and grafted tumors have the same histochemical features as the original culture stock. Up to now, this cell line has produced more than 120 generations in its external culture. At present the cells are growing well, generative processes are stable and preservation is handled in the tumor laboratory of Shanghai Thoracic Hospital.

Reference Literature:

Wu Shanfang [0702 0810 5364], Wang Enzhong [3769 1869 1813], Su Jianzhong [5685 1696 0022], Xu Huixuan [1776 5610 5503], Lin Zhenqiong [2651 7201 8825], Shen Ciyuan [3088 1964 3293], Xu Changwen [1776 2490 2429], Chen Ruiming [7115 3843 6900], Ye Xiuzhen [0673 4423 3791], Zhu Dehou [2612 1795 0624] and Yang Zhenghong [2799 2973 3163], 1984. ZHONGGUO KEXUE [CHINESE SCIENCE], 1:53-57.

(Article written by Zhu Dehou of the Shanghai Institute of Cell Biology, Chinese Academy of Sciences.)

II. Grass-Carp Buccal Tissue Cell Strain ZC-7901 and the Introduction of Substrain ZC-7901 S_1

The ZC-7901 cell line was drawn from buccal epidermis of a young 7~8-month-old grass carp. First, a stationary tissue-mass culture was established. Five to 6 days later those cells which were growing vigorously and profusely on the areola were selected to make a generative culture. The generative

success rate was not very high, and the time it took to grow a single cell layer varied from more than 20 days to more than 2 months. Five to six generations later, the cells gradually stabilized at a generation time of around 4 days. By December of 1979 the cells had been cultured for more than 12 months running, had produced their 63d generation and had established a cell strain named ZC-7901. When these cells had produced their 11th generation, a capillary was used to separate out a substrain therefrom, which was called ZC-7901 S_1. By December of 1979 this substrain had produced its 35th generation. The two cell strains were grown in culture solution 199, containing 15 percent calf's serum, with acidity adjusted to around pH 7 and normal culture temperature at 25-28°C.

Cell strain ZC-7901 is a mixture of epithelioid cells and fusiform cells, and cell strain ZC-7901 S_1 is composed of epithelioid cells. At less than 2-4°C the two cell strains can be preserved for from 7 days to several months; at 12°C there is extremely slow growth and multiplication; at 20°C multiplication accelerates; at 25-28°C multiplication is at its optimum level; at 30-32°C growth is too vigorous and there is rapid aging; and at 36-37°C the cells die. The cell chromosome number is 2n=48 and it stays within this normal range for 120 generations.

In November of 1979 the early generations of the two cell strains were preserved in the Shanghai Institute of Cell Biology of the Chinese Academy of Sciences and in the laboratory of that institute. In June of 1983 resuscitation tests were conducted and the cells were still in good condition so they were returned to preservation under refrigeration.

Reference Literature:

SHIYAN SHENGWU XUEBAO [JOURNAL OF EXPERIMENTAL BIOLOGY], 1981, 3(1):101.

(Written by Zhang Nianci [1728 1819 1964] and Yang Guangzhi [2799 1684 2535], of the Zhejiang Ling Hu Institute of Aquatic Products.)

III. A Hybrid Tumor Cell Line From a Monoclonal Antibody to Epidemic Type-B Encephalitis Virus

This cell line employs splenocytes from mice with a BALB/C immunity to epidemic type-B encephalitis virus strain SA_4, and myeloma cells from mice with an XNS immunity to that virus.

In May of 1982, strain $6B_{11}$ was established.

Of the merged results of 192 experiments, hybrid tumors grew in 64 cases. Through the use of screening tests--trace-enzyme and immunoadsorption trials, microimmunofluorescence and hemagglutination-suppression trials--specific antibodies were produced in five cases. Of these, four strains were lost in the process of culture expansion and cloning and only one, named $6B_{11}$, was established. Successive generations into the 7th month continued to secrete specific antibodies.

After the fourth cloning, within the culture liquor the valence of antibody ELISA was 10^{-2}~10^{-3}, the HI titer was 1:16-1:64, and the IF titer was 1:256; within immune ascitic fluid the valence of antibody ELISA was 10^{-5}~10^{-7}, the HI titer was 1:640 ans the IF titer was 10^{-4}. The chromosomes in this cell line numbered from 74-96, including those having filaments and dots indicating chromosomes. This antibody is a subtype of IgG_3.

The cell line is preserved in liquid nitrogen.

The preserving unit is the Microbiology Teaching and Research Station of the Fourth Army Medical University in Xi'an.

Reference Literature:

JIEFANGJUN YIXUE ZAZHI [MEDICAL JOURNAL OF CHINESE PEOPLE'S LIBERATION ARMY] 1983, 8(2):84.

In October of 1983 the All-Military Scientific Association for Coordination of Monoclonal Antibodies read out, appraised and approved the establsihment of this strain.

(Written by Wang Meixian [3076 5019 0341, Cui Yunghang [1508 6663 2490], Xiang Bingyi [7309 4426 2034], Yu Biyun [0060 4310 0061] and Ma Wenyu [7476 2429 3558] of the Fourth Army Medical University.)

IV. A Hybrid Tumor Cell Line From a Monoclonal Antibody to Renal Syndrome Hemmorhagic Fever Virus

Employs Splenocytes from mice with BALB-C and CXS-2 immunities to renal syndrome hemmorhagic fever virus 82-010 H, which was isolated from the serum of patients in Shaanxi, and the meloma cells of mice with SP 2/OAg 14 immunity to that virus.

In May 1983, 10 strains were established, including strains 4 B9 and 3 H4. Through cell staining and karyotype analysis and through antibody immunoglobulin-type appraisals, strains 4 B9 and 3 H4 both have proven to have established hybrid tumor cell lines from secretion-specific antibodies.

Through direct immunofluorescence trials, strains 4 B9 and 3 H4 monoclonal antibodies detected antigens to 13 renal syndrome hemmorhagic fever virus strains isolated in various parts of the country. The result demonstrated that strain 4 B9 monoclonal antibody is capable of distinguishing between viruses from plague zones of the black-striped ji [1213]-mouse (Shaanxi, Anhui and Jiangsu) and those from plague zones of the brown rats (Shanxi and Henan) and the greater forest ji-mouse (Heilongjiang and Jilin). Strain 3 H4 monoclonol antibody is capable of further differentiating between viruses from the plague zones of the above black-striped ji-mouse and those of brown rats.

The two strains 4 H9 and 3 H4 have produced ascitic fluid for identification and other uses. These cell lines are preserved in liquid nitrogen. The other eight strains of cell lines that were orignallly screened out are in the process of being recovered, cloned and identified.

The preserving unit is the Microbiology Teaching and Research Station of the Fourth Army Medical University in Xi'an.

Reference Literature:

DISI JUN YI DAXUE XUEBAO [JOURNAL OF THE FOURTH ARMY MEDICAL UNIVERSITY] 1984, 5:1.

In October of 1983 the All-Military Scientific Association for Coordination of Monoclonal Antibodies read out, appraised and approved the establsihment of these strains.

(Written by Wang Meixian, An Xianlu [1344 3759 6922], Xu Zhikai [1776 1807 0418], Li Enshan [2621 1869 0810], Zhen Rongfang [3914 2837 5364] and Jiang Kejian [1203 0344 0313] of the Fourth Army Medical University.)

12510
CSO: 4008/63

LIFE SCIENCES

BRIEFS

LIAONING REPORT SYSTEM FOR TUMORS--Shenyang, 11 Jan (XINHUA)--The health department in Liaoning Province, northeast China, has set up a system for reporting malignant tumors starting this year. It aims to find out the incidence law and the causes, department authorities said. Malignant tumor has become the number two killer in the province while it placed 7th in 1957. One out of every four dead persons died of it. Meanwhile acute infectious diseases declined from third to tenth place. Now, the province has set up a tumor hospital with 400 beds with a research institute. All the general hospitals have tumor departments. Malignant tumor is third in death causes in the country. Number one killer is cerebrovascular diseases followed by heart attacks. [Text] [Beijing XINHUA in English 1834 GMT 11 Jan 85 OW]

CSO: 4010/66

ENVIRONMENTAL QUALITY

PRC STRENGTHENS ENVIRONMENTAL PROTECTION WORK

OW221615 Beijing XINHUA in English 1438 GMT 22 Jan 85

[Text] Beijing, 22 Jan (XINHUA)--In the past year China has set up powerful leading bodies for environmental protection, made relevant laws and regulations and tapped financial sources, Qu Geping, director of the state administration for environmental protection, said here today.

Addressing an opening session of a national meeting on environmental protection, Qu said a commission for environmental protection was set up last May under the State Council with Vice-Premier Li Peng as the minister in charge, and in November the state administration for environmental protection was set up to be responsible for guiding and coordinating environmental protection throughout the country. The leadership of local governments in environmental protection also was strengthened in varying degrees, Qu said. Environmental protection bureaus were set up in 14 provinces and municipalities last year.

At the Second National Conference on environmental Protection convened last year, eight channels for accumulating funds were defined, including collecting pollutant-discharge fees, deducting depreciation fees of fixed assets and retaining seven percent of the funds for technical transformation for the purchase of environmental protection equipment.

In 1984, a total of four billion yuan was accumulated for this purpose, accounting for over 0.4 percent of the total national output value.

At the converence, environmental protection was defined as a basic national policy.

Last year a series of laws and regulations were promulgated and put into effect. These included the "Water Pollution Prevention and Control Law of the People's Republic of China" which is a sub-section of the "Environmental Protection Law of the People's Republic of China", "Regulations for Strengthening Environmental Control of Rural Township and Street Enterprises", "Prevention of Soot Pollution", and "Trial Targets for Examining Environmental Protection in Industrial Enterprises." The state administration for environmental protection also drafted "Noise Pollution Law," "Air Pollution Law," "Rules and Regulations on Managing Nature Reserves" and "Rules and Regulations on Protecting Rare and Endangered Animal and Plant Species."

Last year the supervision of the urban environment was stepped up and 22 automatic atmospheric observation stations were built, putting the total number of observation posts at 1,143 nationwide.

According to incomplete statistics, more than 150 conspicuous pollution projects were tackled in 22 provinces and municipalities last year.

During the same period, a large number of cities cut down noise by three to seven decibels, the noise in Chengdu, Xian and Nanchang dropped by eight to nine decibels.

China added more than 25 million square meters of central heating space in 1984, when the number of cities having central heating facilities reached 70. Some scenic spots and downtown streets in Beijing, Shanghai and Hangzhou became smoke-free.

In 1984 more than 30 rivers and lakes in 22 provinces and municipalities were cleared of pollution, including two rivers in Beijing.

A sewage treatment plant with a daily capacity of 260,000 tons a day, the largest so far in China, was built in Tianjin last year.

CSO. 4010/65

ENVIRONMENTAL QUALITY

PLUTONIUM LEVELS IN BEIJING'S SOIL, WATER

Beijing HUANJING KEXUE /JOURNAL OF ENVIRONMENTAL SCIENCE/ in Chinese No 5, 30 Oct 84 pp 10-13

/Article by YAN Qimin /7346 0796 3046/ and LIU Shousun /0491 1108 5549/ of Institute of Atomic Energy, Chinese Academy of Sciences, and CHEN AIMIN /7115 1947 3046/ of Quarantine Station, Beijing Municipality: "Analysis of Plutonium Levels in Soil and Water in Beijing Area"/

/Summary/ In analyzing the sources of plutonium contamination, considering effects caused by global fallout and local contamination is helpful by measuring the levels of ^{238}Pu and ^{239}Pu. Human beings are affected by plutonium contamination; the main routes are: (1) inhaling plutonium contaminated air: (2) eating plutonium-contaminated food; and (3) through the food chain. Plutonium-contaiminated soil may release the element into the atmosphere. Therefore, analysis of plutonium levels in air and water is a principal way of discovering plutonium contamination of the environment.

The vertical distribution of plutonium concentrations in soil is related to the different types of soil: sandy soil, loess and clay in this study. The main distribution of plutonium fallout from the atmosphere is in topsoil down to a depth of 10 cm. The highest concentrations of plutonium in Beijing-area soil appeared in 1963. Compared to the years before 1964, ^{238}Pu to ^{239}Pu ratios in soil appreciably rose in 1980 and 1981; this was caused mainly by global contamination. Most plutonium concentrations in Beijing-area water are lower than the lowest detectable limit.

Four figures show the alpha spectra of plutonium in soils near the Institute of Atomic Energy and in Miyun County. Four tables show plutonium concentrations in soil and water, vertical distribution of plutonium in soil, and the ^{238}Pu to ^{239}Pu ratios.

10424
CSO: 4009/76

ENVIRONMENTAL QUALITY

GROUNDWATER NITROGEN POLLUTION, FARMLAND FERTILIZATION, SEWAGE IRRIGATION

Beijing HUANJING KEXUE /JOURNAL OF ENVIRONMENTAL SCIENCE/ in Chinese No 5, 30 Oct 84 pp 43-47

/Article by DONG Keyu /5516 0344 5713/, CHEN Jiamei /7115 1367 2734/, WANG Qingmin /3769 1987 2404/ and HUANG Deming /7806 1795 2494/ of Academy of Agriculture and Forestry, Beijing Municipality: "Correlation Between Nitrogen Pollution of Groundwater and Fertilizer Applied to Farmland as Well as Sewage Irrigation in the West Suburb of Beijing"/

/Summary/ Beijing's west suburbs have abundant groundwater reserves, situated upstream of Beijing's surface and underground water. Therefore, keeping west suburb groundwater free from pollution is vital to the capital's industrial and agricultural production and to public health. In 1981 and 1982, the authors took part in a cooperative team studying protective measures for water resources in Beijing's west suburbs. Nitrogen pollution in groundwater, and the causes of nitrogen pollution by farm fertilization and sewage irrigation were studied. The highest concentration of nitrogen in west suburb groundwater is in the nitrate form, averaging 5.78 ppm. In the high water-flow period (October), the nitrate concentration in groundwater averages 10.73 ppm, which exceeds the sanitation norms of the United States and the World Health Organization. It is apparent that west suburb groundwater is polluted with nitrates. This stems from nitrogen fertilizer applied to farmlands and truck farms in the suburbs in excess of 50 to 100 percent to the amounts absorbed by crops. The reason for excess nitrogen in soil is due to insufficient amounts of organic manure and phosphorus fertilizer, and the application of large amounts of nitrogen fertilizer just before Beijing's rainy season (July and Ausut). This is why nitrogen pollution of groundwater is high in October but low in June (the low water-flow period). In the sewage irrigation area, Beijing's west suburbs, the soil layer is thin with rapid percolation downward. Since there is high nitrogen but low phosphorus content in sewage, this further builds up nitrogen concentration in soil and water.

It is proposed that more phosphorus fertilizer should be applied to farmland in the groundwater supply zone in order to increase the N/P_2O_5 ratio from the present 1:1.01--1:0.20 to 1:0.5 and upwards; even more phosphorus fertilizer should be applied in the sewage irrigation zone. The ecological environment of the rapid downward percolation zone should be strictly protected by only working organic and green manure into the soil. A more drastic approach may be adopted to prohibit sewage irrigation if nitrogen pollution worsens.

One figure shows nitrogen fertilizer sales in different months in Beijing. Nine tables show groundwater nitrate concentrations average annual application of chemical fertilizer, nitrogen from organic and chemical fertilizers, nitrogen concentrations in soil of potted plants, sewage irrigation, nitrogen concentration in surface water, irrigation water and its nitrogen concentration, and indoor water percolation tests.

10424
CSO: 4009/76

ENVIRONMENTAL QUALITY

BRIEFS

TAIYUAN POLLUTION MONITORING--Taiyuan, 19 Jan (XINHUA)--Extensive winter atmospheric monitoring has begun around Taiyuan, capital of Shanxi Province, to determine maximum pollutant discharge and distribution. Scientists say this may help environmental protection in the Taiyuan area and planning and renovation of other hill cities. It is one of 38 research projects for the 1981-1935 five-year plan. The 500 monitoring staff are from the China Environmental Science Academy and other bodies. They are covering over 2,000 square kilometers around Taiyuan with planes, radar and motorboats. As a center of coal mining and chemical industry, Taiyuan is among the country's worst polluted cities. Monitoring will end on 25 January. [Text] [Beijing XINHUA in English 0703 GMT 19 Jan 85 OW]

CSO: 4010/65

SCIENTISTS AND SCIENTIFIC ORGANIZATIONS

XIANG NAN RECEIVES MICROCOMPUTER EXPERTS

OW081832 Fuzhou FUJIAN RIBAO in Chinese 22 Nov 84 p 1

[Excerpts] The second symposium on the application of microcomputers opened in Xiamen University today. Attending were over 500 experts, professors, research fellows, engineers, and scientific and technological workers from across the nation.

Over the past 2 years since China's first symposium on the application of microcomputers, the rapid development of microcomputers and microcomputer technology has been witnessed at home and abroad. The giant steps taken by various departments in China in the application of microcomputer technology have had a positive impact on the entire national economy. In response to the call of the CPC Central Committee and the State Council, the Chinese Microcomputer Application Association has sponsored the current symposium to step up research in and popularize applied microcomputer science.

On behalf of the Provincial CPC Committee and the Provincial Government, Huang Changxi, vice governor of Fujian Province, greeted the meeting. He said: Convening the second China symposium on microcomputers application in Xiamen not only would serve as powerful support to Fujian in its effort to implement the policies of opening to the outside world, enlivening the domestic economy, and carrying out economic structural reform, but would also give a great encouragement to and spur on Fujian's scientific and technological circles. He hoped that the symposium would help spread the use of microcomputers in Fujian and promote its economic construction.

Prior to the opening of the symposium, Xiang Nan, first secretary of the provincial CPC committee, received a number of experts attending the meeting.

CSO: 4008/184

AUTHOR: XU Lu [6079 4389]
LI Guoquan [2621 0948 2938]
HUANG Benli [7806 2609 4539]
et al.

ORG: All of Changchun Institute of Applied Chemistry, Chinese Academy of Sciences

TITLE: "Microcomputerized Emission Spectrographic Microphotometry. II. Microcomputer-Controlled Automated System"

SOURCE: Changchun FENXI HUAXUE [ANALYTICAL CHEMISTRY] in Chinese No 7, 20 Jul 84 pp 626-629

TEXT OF ENGLISH ABSTRACT: A Z-80 based on a microcomputer is used to control the movement of the plate-carriage of the modified Zeiss G II microphotometer. Its x- and y- direction movements are driven by step motors via a precise lead screw and a rack-and-pinion mechanism, respectively. The plate is moved in the x-direction at a speed of 800 μm/sec, and only very small portions of the spectrum, the so-called sampling gates or windows, each encompassing an analytical line, are measured at intervals of 2 μm. After all analytical lines in one spectrum are measured, the photoplate is shifted to the next spectrum along the y-direction and the measurement is restarted. For locating the analytical lines, a dispersion equation has been obtained experimentally by measuring the position of a group of lines of known wavelengths relative to a "zero" reference line. The system has been used to determine thulium and lutetium in rare earth mixtures with satisfactory results.

9717
CSO: 4009/75

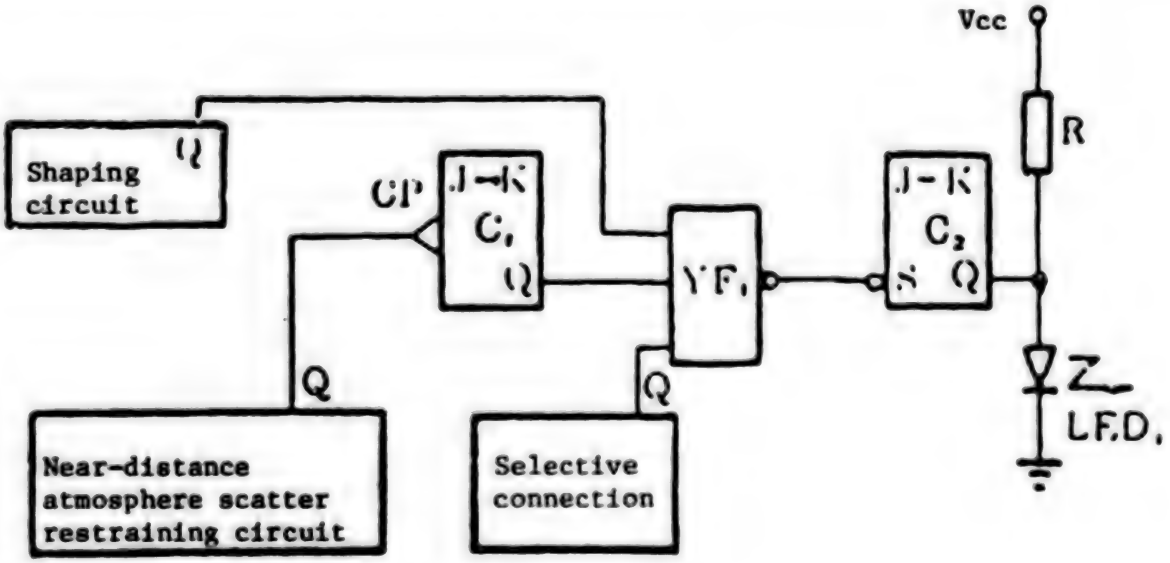
AUTHOR: GU Zhiyuan [7357 1807 6678]

ORG: Huaguang Instruments Plant

TITLE: "Target Display Circuit in Laser Range Finder"

SOURCE: Shanghai YINGYONG JIGUANG [APPLIED LASER] in Chinese Vol 4 No 4, Aug 84 pp 183-184

ABSTRACT: A simple but practical target display circuit incorporates Chinese-made elements. The target display circuit can simultaneously display three targets; the near and distant targets are displayed with light spots, which provide visual guidance for the shooter. The entire circuit consists of a near-target display circuit and a distant-target display circuit. The near-target display circuit is shown by the following schematic:



Near-target Display Circuit

When there is an echo wave from multiple targets, the corresponding output at terminal Q consists of positive pulses of the echo wave from multiple targets through photoelectric conversion, amplification and the shaping circuit. If the second target is to be surveyed, the first target can be expelled merely by adjusting the switching potentiometer. Another schematic shows a distant-target display circuit. The two remaining figures show time sequence diagrams of the near- and distant-target display circuits. The advantages of circuits of this kind are simplicity, reliability, no limitation on the number of targets, stable performance, satisfactory tests of the device in range finding, and adaptation to environmental temperatures between -40°C and +50°C.

10424
CSO: 4009/33

AUTHOR: LOU Qihong [2869 4388 3163]

ORG: Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences

TITLE: "Improvement of Excimer Laser Output Characteristics by Using a Hybrid Unstable Resonator"

SOURCE: Shanghai YINGYONG JIGUANG [APPLIED LASER] in Chinese Vol 4 No 4, Aug 84 pp 158-160

ABSTRACT: Three types of laser resonator configurations (stable resonator, parallel-plane resonator, and hybrid unstable resonator) were tested with a high-gain excimer laser by measuring the far-field beam quality. Experimental results showed good beam quality by transmission through a partially transparent mirror; the divergent angle of the excimer laser can be reduced to several milli-radians. Using an excimer laser requires that the laser has a beam with good quality. For example, if an excimer laser is used in nonlinear optical experiments (Raman scattering, among them), it is required that the laser beam has a relatively small divergent angle. In the event the excimer laser is used for optical etching and material treatment, it is required that the laser beam should produce uniform laser spots. Generally, a parallel-plane resonator or a toroidal laser output with an unstable resonator is used to improve laser beam quality; however, the laser spots of toroidal output are not desirable for near-field applications. Therefore, in this paper, a hybrid unstable resonator was used to improve excimer laser output characteristics. Four figures show the calculation of a unstable resonator toroidal laser output far-field distribution, the relationship between the divergent angle and amplifying factor when the divergent angle is at the diffraction limit, an experimental layout for comparing output characteristics of various resonators, and a comparison of laser orientation for different resonator configurations. One table shows parameters and characteristics of several resonator configurations. The paper was received for publication on 17 March 1984.

10424
CSO: 4009/33

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TITLE: "Study of Beam Electron Profile of Glow Discharge Electron Gun Used for Transverse Ion Lasers"

SOURCE: Shanghai YINGYONG JIGUANG [APPLIED LASER] in Chinese Vol 4 No 4, Aug 84 pp 161-162 & 160

ABSTRACT: The beam electron profile of a new electron gun has been directly measured; this electron beam has been applied in continuous ion lasers. The spatial uniformity of the electron beam has been improved by static field modification. By using a new ion laser excited by a glow discharge electron beam, radiation from (multiple metals) continuous ion laser has been achieved. A glow discharge electron gun for transverse continuous excitation was developed for miniaturization and practicability of laser equipment. The electron beam from the gun can also be used in rapid treatment processes in making integrated circuits. For the first time in 1982, this electron gun was used successfully in annealing silicon chips. This paper presents a simple reliable method of directly observing beam electron profiles. In addition, methods and results of improving spatial uniformity of electron beams are studied. Three figures show the spatial distribution of beam electron densities, electrode modification, and the spatial distribution of beam electron densities following electrode modification. The authors express their gratitude to Professor G. Collins for his counsel, to colleague Weng Yumin [5040 3254 3046] for his assistance, and to the Shanghai Electrovacuum Institute for their supply of fluorescent screens. The paper was received for publication on 7 May 1984.

10424
CSO: 4009/33

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ORG: All of Beijing Institute of Optoelectronic Technology

TITLE: "Nitrogen Laser With 6 mJ Pulse Energy at 20 Hz"

SOURCE: Shanghai YINGYONG JIGUANG [APPLIED LASER] in Chinese Vol 4 No 4, Aug 84 pp 171-174

ABSTRACT: The paper reports on improvements in a capacitor-dumped nitrogen laser developed by the authors. Pulse energy, average power, peak power, beam quality and reliability have been enhanced. Output energy of 11.5 mJ at 1 Hz, or 6.7 mJ at 20 Hz, reliability of ±5.5 percent, pulse length of 4.5 ns, peak power of 1.5 MW and average power of 122 MW were achieved. In discussing how to greatly increase average laser power, the authors aimed at solving three problems: speeding up the gas exchange, optimal selection of capacity of energy storing capacitor, and selection of such capacitor with low inductance and high-voltage-proof capability. Also discussed in the paper are increased service life and stability of sphere gap electrode, relationship between laser peak power and working gas pressure, enhancement of beam quality, stability of average laser power, and performance of a model QJD-9 N_2 laser. Five figures show the gas flow direction at a laser cavity cross-section, measurement of gas pressure at points within the cavity, capacitor-dumped circuit, pulse waveforms at different gas pressures (10 Hz in frequency), and the exterior of a model QJD-9 N_2 laser (including power supply). The paper was received for publication on 21 April 1984.

10424
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Thought Experiments

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TITLE: "Thought Experiment - Introducing a Technique of Scientific Research"

SOURCE: Shanghai ZIRAN ZAZHI [NATURE JOURNAL] in Chinese No 11, 1983 pp 807-809

ABSTRACT: The paper defines the term 'thought experiment' as a way of carrying on experiments without the need of making samples, instruments, or equipment. Without specifically mentioning Einstein's mass-energy thought experiment [1905] the paper states that many famous scientists such as Einstein, [Niels] Bohr, [Werner] Heisenber, etc. obtained profound results with this method. The theory of bending of light in a gravitational field and the basic concepts of quantum mechanics are briefly described to illustrate the power of thought experiment. In itself, the paper further states, thought experiment cannot replace scientific experiment. In order to improve China's backwardness in science and technology, without doubt, tools of observation and experimentation must be developed, but they require a great deal of time, manpower and materials. The paper suggests that methods of "concrete experiment" should be combined with thought experiment in order that China's deficiency of materials may be made up with brain labor to raise efficiency and to reduce waste.

6248
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Oceanology

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TITLE: "Changes of Electrical Activity of the Human Heart in A Simulated 302m Helium Oxygen Satuation Submergence Experiment"

SOURCE: Beijing HAIYANG XUEBAO [ACTA OCEANOLOGICA SINICA] in Chinese No 3, May 84 pp 415-422

ABSTRACT: Participants of the experiment included 3 healthy, trained, male divers, aged 24-29. The pressure of the test chamber was brought to 5m first with air, then to 100m with helium. After an interval of half an hour, the pressure was increased to 200m at a speed of 12m/hour, and after a rest period of 11 hours, to 302m. Decompression began 43.5 hours later. A Life Scope-8 heart monitor made by the Kohdeh Co of Japan was used to record the EKG of the participants during all stages of the experiment. Compression type slowed heart beat and sinus arrhythmia were observed and the effects of pressure increase, exposure to 302m satuation, and the decompression process on the electrical activity of the heart recorded. The heart rate was observed to increase much more obviously following exercise under normal pressure to indicate a reduction of work capacity of the diver under the condition of high pressure. Some EKG records are analyzed in the paper.

6248
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Radiology

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TITLE: "Radiological Observations of Pulmonary Edema due to Phosgene Poisoning"

SOURCE: Beijing ZHONGHUA FANGSHEXUE ZAZHI [CHINESE JOURNAL OF RADIOLOGY] in Chinese No 3, 10 Aug 84 pp 171-173

ABSTRACT: Phosgene is an important industrial chemical but it is also a poisonous gas, causing suffocation in the respiratory passages. Not infrequently, it causes poisoning due to inhalation of phosgene during its synthesis and utilization. A radiologic observation of pulmonary edema following phosgene inhalation was made and the chest films of eight victims were analyzed.

The pulmonary edema caused by acute phosgene poisoning can be classified into three types; diffuse, central and focal. The X-ray findings were described in detail in correlation with the clinical symptoms. In addition, the causative mechanism of pulmonary edmea by phosgene gas was discussed. The role of X-ray examinations in diagnosing phosgene poisoning and its characteristic radiologic manifestations were also investigated.

Generally, pulmonary edema is related to the amount of phosgene gas inhaled. Its inhalation at concentrations between 30 and 60 mg/m^3 may cause serious poisoning. Death may result if first aid is not swiftly applied. For patients with mild poisoning, edema may not occur.

Three inset negatives show three types of edema.

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Silicates

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TITLE: Microporous Glass for Immobilization of Enzymes

SOURCE: Beijing GUISUANYAN XUEBAO [JOURNAL OF THE CHINESE SILICATE SOCIETY] in Chinese No 2, Jun 84 pp 193-201

ABSTRACT: Various kinds of microporous glasses with pore diameter ranging from 80Å to 1500Å were prepared by changing the Na_2O-B_2O_3-SiO_2 formulation. The pore diameter distribution and specific surface area for each glass composition were determined experimentally. The effects of heat treatment, dilute acid leaching and pore enlargement were investigated. It was found that glass composition is the determining factor. Glucoamylase was immobilized on these glasses. Its activity increased with decreasing glass grain size, increasing pore diameter and specific area. A 750Å pore diameter microporous glass containing more than 90 percent silicon dioxide with a 40-80m^2/g specific area and 0.71-1.00cm^3/g pore volume is most suitable for glucoamylase immobilization. In addition to glucoamylase, this microporous glass technique was successfully used to immobilize penicillinase as well as other enzymes such as alkaline protease, α-amylase, as paraginase and penicillin acylase. The microporous glass could be chemically regenerated with an oxygen containing acid.

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